SUPPLEMENT

TO BRITISH TELECOMMUNICATIONS ENGINEERING

(formerly the Supplement to The Post Office Electrical Engineers' Journal)

Vol. 5 Part 1 April 1986

ISSN 0262-4028

BTEC & CGLI
GUIDANCE FOR STUDENTS
EDUCATIONAL PAPER

Contents

BUSINESS AND TECHNICIAN EDUCATION COUNCIL

Certificate Programme in Telecommunications

Sets of model questions and answers for Business and Technician Education Council (BTEC) units are given below. The questions illustrate the types of questions that students may encounter, and are useful as practice material for the skills learned during the course.

Where additional text is given for educational purposes, it is shown within square brackets to distinguish it from information expected of students under examination conditions. Representative time limits for questions are shown, and care has been taken to give model answers that reflect these limits.

We would like to emphasise that the questions are not representative of questions set by any particular college.

BTEC: LINES III

The questions in this paper are based on the BTEC's standard unit U81/756. Students are advised to read the notes above.

Q1 *(a) Draw diagrams of*

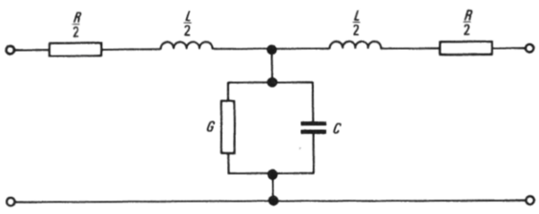
(i) a T section, and
(ii) a π section

of a uniform transmission line.

List the primary coefficients, and state the usual units of measurement.

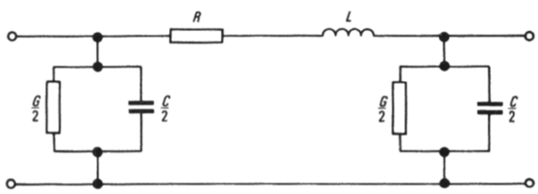
(b) A line can be considered to be a uniform resistive line with the values of conductor resistance $Z_1 = 600\,\Omega$ and insulation resistance $Z_2 = 12\,k\Omega$. Show how the line can be represented as a balanced T network and calculate the value of the characteristic impedance. *(20 min)*

A1 *(a) (i)* A T section of a uniform transmission line is shown in sketch *(a)*.



(a)

(ii) a π section from the line is shown in sketch *(b)*.

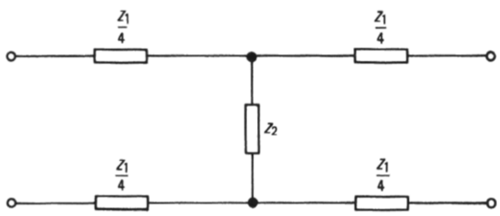


(b)

The primary coefficients of the line are

series resistance (*R* ohms/kilometre loop),
inductance (*L* henrys/kilometre loop),
capacitance (*C* farads/kilometre), and
leakage (*G* siemans/kilometre).

(b) A uniform resistive line can be drawn as shown in sketch *(c)*.



(c)

For a purely resistive line, the value of the characteristic impedance, Z_0, can be found by using the expression:

$$Z_0 = \sqrt{(R_{oc} \times R_{sc})},$$

where R_{oc} is the input resistance of the network with the output open circuit, and R_{sc} is the input resistance with the output short circuited.

Now,

$$R_{sc} = 300 + \frac{12 \times 10^3 \times 300}{12 \times 10^3 + 300},$$

$$= 300 + \frac{36 \times 10^5}{12{\cdot}3 \times 10^3},$$

$$= 300 + \frac{3600}{12{\cdot}3},$$

$$= 592{\cdot}68 \approx 593.$$

And,
$$R_{oc} = 300 + 12\,000,$$
$$= 12\,300.$$
$$\therefore \quad Z_0 = \sqrt{(12\,300 \times 593)},$$
$$= \underline{2700{\cdot}7}.$$

Q2 *(a) The magnitude of a current (I_L) measured L kilometres along a uniform transmission line terminated in its characteristic impedance can be calculated by the formula (tick correct answer):*

(i) $I_L = I_s e\alpha^L$
(ii) $I_L = I_s e^{-\alpha L}$
(iii) $I_L = I_s L^{-e}$
(iv) $I_L = I_s \log_e \alpha L$,

where α is the attenuation coefficient, and I_s is the sending-end current.

(b) If I_1 and I_2 are the magnitudes of the current at the beginning and end of a line that is 1 km long and terminated in its characteristic impedance, derive an expression for the value of the attenuation coefficient in terms of I_1 and I_2.

(c) A voice-frequency signal of 796 Hz is transmitted along an unloaded cable of negligible inductance and leakage conductance, and with primary coefficients of $R = 176\,\Omega$/km loop and $C = 0{\cdot}065\,\mu F$/km. Calculate, for this cable, justifying any approximations made:

(i) the attenuation coefficient,
(ii) the phase-change coefficient,
(iii) the velocity of propagation, and
(iv) the wavelength. *(20 min)*

A2 *(a) (ii)* $I_L = I_s e^{-\alpha L}$

(b)
$$\frac{I_2}{I_1} = e^{-\alpha} \quad (\text{as } L = 1, \alpha L = \alpha).$$
$$\therefore \quad e^{\alpha} = \frac{I_1}{I_2}.$$
$$\therefore \quad \alpha = \log_e \frac{I_1}{I_2}.$$

(c) As the question states that the inductance and the leakage conductance are negligible, then
$$\omega L \gg G \quad \text{and} \quad R \gg \omega L,$$
where ω is $2\pi \times$ frequency.

The effect of both G and ωL can be ignored, and the appropriate approximations used.

(i) The attenuation coefficient, α, is given by
$$\alpha = \sqrt{\left(\frac{R\omega C}{2}\right)} = \sqrt{\left(\frac{0{\cdot}0572}{2}\right)} = \underline{0{\cdot}169\ \text{Np/km}}.$$

(ii) The phase-change coefficient, β, is given by
$$\beta = \sqrt{\left(\frac{R\omega C}{2}\right)} = \underline{0{\cdot}169\ \text{rad/km}}.$$

(iii) The velocity of propagation, u, is given by
$$u = \frac{\omega}{\beta} = \frac{5000}{0{\cdot}169} = \underline{29\,560\ \text{km/s}}.$$

(iv) The wavelength, λ, is given by
$$\lambda = \frac{2\pi}{\beta} = \frac{6{\cdot}28}{0{\cdot}169} = \underline{37{\cdot}15\ \text{km}}.$$

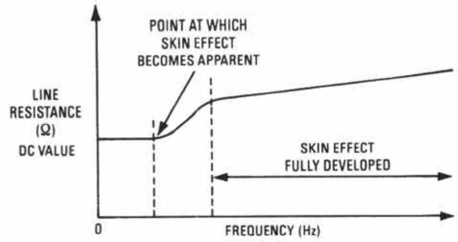
Q3 *(a) Explain the term 'skin effect', with regard to the current density of an AC signal flowing through a conductor. Sketch a graph to illustrate how the resistance of a transmission line is affected by the skin effect as the frequency of the line current is increased. State the effect on the losses due to the skin effect of increasing the diameter of the conductor.*

(b) Explain how the inductance of a conductor is affected by the skin effect; illustrate your explanation with a graphical sketch of the inductance versus frequency. *(25 min)*

A3 *(a)* An alternating current flowing through a conductor produces a changing magnetic flux which, in turn, induces a back EMF into the conductor. The extent of the back EMF is proportional to the magnitude of the flux, which is dependent on the frequency of the current.

Since, in a circular cross-sectioned conductor, the magnetic flux is greatest in the centre, it follows that the back EMF is also greater in the centre. As the back EMF opposes the flow of current, the current density is less at the centre than at the surface of the conductor. As the frequency increases, and hence the magnetic flux increases, the current tends to flow only in the outer parts, or 'skin' of the conductor. This is called the *skin effect*.

At high frequencies, the resistance of a transmission-line conductor can be shown to be proportional to the square root of the frequency ($\sqrt{f}$). The effect of the skin effect on the resistance of the line as the frequency is increased is shown in sketch *(a)*.



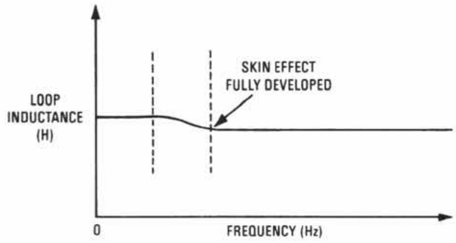
(a)

The effect of increasing the diameter of the conductor is to reduce the loss due to the skin effect. However, the greater the diameter of the conductor, the higher the cost of the conductor because of the additional materials.

(b) The inductance of a conductor is proportional to the magnetic flux linkages set up by the current. Therefore, it is also affected by the skin effect, because the change in current distribution over the cross-section of the conductor alters the magnetic flux linkages.

When a conductor carries a current, some of the magnetic flux (the internal components) exists within the conductor. It is this portion that links with the centre of the conductor, while not linking with the material nearer the surface. As a result, the inductance of the conductor is greater at the centre than nearer the surface. This is because of the greater number of flux linkages occurring in the centre portion as the flux grows and decays.

This internal component of the inductance is inversely proportional to $\sqrt{f}$. It is much smaller than the external component, which is almost independent of frequency. Sketch *(b)* shows how the inductance of a conductor varies with frequency.



(b)

As the frequency is increased, the inductance initially remains constant at its DC value until the skin effect becomes apparent. It then decreases until the skin effect is fully developed, and stabilises at a value slightly lower than the DC value.

Q4 *(a) State six advantages of optical-fibre systems over traditional coaxial cable transmission lines.*

(b) With the aid of a sketch, explain what is meant by a ray of light undergoing 'refraction' when passing through a block of glass.

When striking a stream of fresh water, a ray of light has an angle of incidence of 37° and an angle of refraction of 26°. What is the refractive index (μ)?

(c) Why is ordinary household glass unsuitable for use in optical-fibre cables?

(d) Describe briefly multimode transmission; illustrate your answer with a simple sketch. Explain why multimode dispersion is a problem of multimode fibre, and include an estimation of the approximate spectral spread for both a laser and a light-emitting diode (LED) light source. *(25 min)*

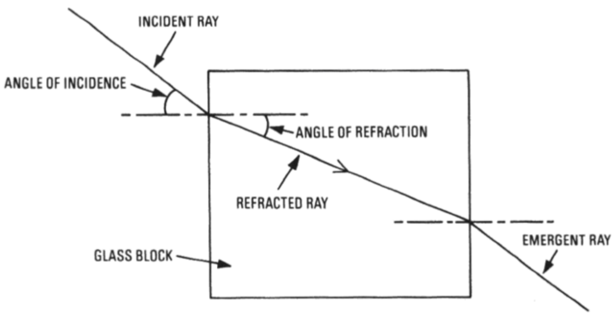
A4 *(a)* The advantages of an optical-fibre system over a traditional coaxial cable line include:

(i) very large information bandwidth and, therefore, a potentially

high transmission rate;
(*ii*) potentially low material cost;
(*iii*) small cable size, leading to low duct occupancy;
(*iv*) negligible crosstalk;
(*v*) high immunity to interference;
(*vi*) complete electrical isolation; and
(*vii*) larger repeater spacings than for metallic-cable systems of equivalent capacity.

[*Tutorial Note:* Seven main advantages listed.]

(*b*) Sketch (*a*) shows how a ray of light is affected when it passes through a block of glass.



(*a*)

Light travels at different speeds through different substances. This causes the light beam to bend or 'refract' as it passes from one medium to another (for example, from air to glass). Each medium has a constant, symbol μ, known as the *refractive index*, which determines how far the ray is bent.

The refractive index is the ratio between the sine of the angle of incidence of the incidence ray to the sine of the angle of the refracted ray:

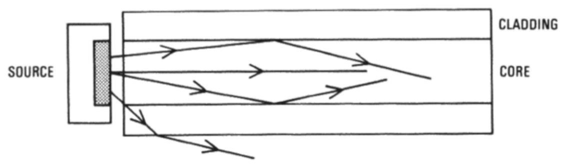
$$\mu = \frac{\sin i}{\sin r}.$$

Substituting the values given in the question:

$$\mu = \frac{\sin 37^\circ}{\sin 26^\circ} = \frac{0{\cdot}6018}{0{\cdot}4384} = \underline{1{\cdot}37}.$$

(*c*) Ordinary household glass is not suitable for optical-fibre cables because it is not sufficiently pure for the economic transmission of light.

(*d*) When light is injected into a fibre, a number of rays of light (or modes) enter the fibre at different angles. The number of modes at any one wavelength is determined by the numerical aperture and the diameter of the core. To achieve maximum efficiency between source and fibre (that is, all the light created by the source enters the fibre), the diameter of the source should be no greater than the core. (See sketch (*b*).) In this situation, there are several rays of light propagating down the fibre. This is called *multimode transmission.*



(*b*)

Although all the rays travel at the same speed, they all take slightly different paths, and therefore reach the far end at different times. This effect, known as *multimode dispersion*, causes problems in the detection of the received light pulses. If a short pulse is launched into the fibre, the output pulse is spread in time. Also, the light source does not have a single characteristic wavelength, but covers a small range, termed the *linewidth* or *spectral spread* and specified in nanometres (nm). For a laser, the linewidth can be 1–4 nm, whereas for an LED it can be 40 nm.

Q5 (*a*) *State why, on a transmission line, a signal wave can be reflected back to the source, from the direction of the termination.*

(*b*) *Describe the condition of termination of the transmission line that produces the current wave effect shown in Fig. 1.* *(10 min)*

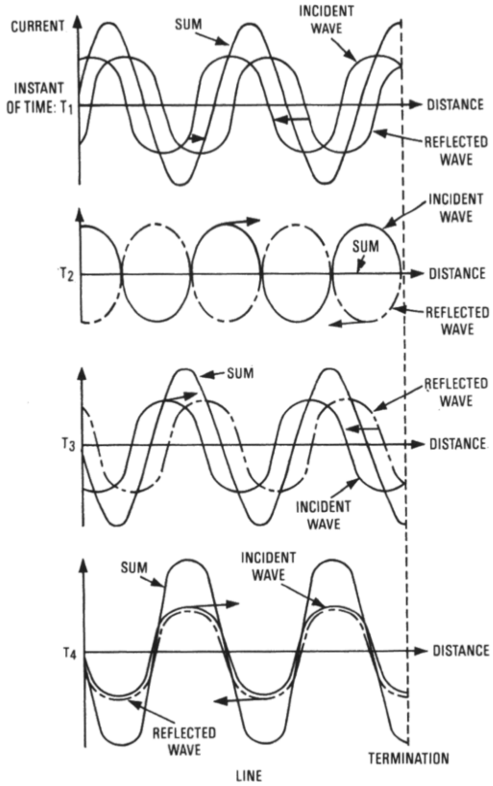


Fig. 1.

A5 (*a*) Reflections occur in all cases where an incident wave meets a point where the continuity of the line is disturbed; for example, at a faulty joint. However, the main cause of reflections is a mismatch of a line with the signal source, because of mis-termination.

(*b*) At the termination of the line, the current is shown as undergoing no phase shift in time as it becomes a reflected wave. Therefore, the reflected wave reinforces the incident wave at the termination. This is the condition that would be expected in a line that was short circuited; that is, there is a maximum current at the short-circuit termination.

Q6 (*a*) *Explain why, for reasons of economy, the conductor diameter of a cable pair from the exchange to a telephone instrument often varies in size from section to section over its length.*

(*b*) *Explain how the signalling and transmission limits of a cable can restrict the geographical size of a telephone area. Suggest one method in common use whereby a demand for telephone service that lies just outside the specified cable limits can be satisfied.*

(*c*) *Explain why it was considered necessary to adopt a national transmission plan. With the aid of a sketch show the transmission limits on each junction of a route from local exchange to local exchange taken by a trunk call which passes through two group switching centres (GSCs).* *(25 min)*

A6 (*a*) The conductor size chosen for a cable route is that which is the most economical, yet meets the transmission and signalling limits. Connections near to the exchange need only small-diameter cables and, as cables nearest to the exchange are likely to be high capacity, maximum economy is achieved by using small-diameter conductors, such as 0·4 mm. However, small conductor diameters would provide for a very small geographical area (which, in fact, is sometimes the case for high-density telephone penetration areas such as city centres). But, generally, a heavier gauge cable is needed as the exchange catchment radius is increased. This leads to a telephone line consisting of a mixture of different conductor gauges, gradually increasing in size along its length.

(*b*) Each telephone exchange has a signalling and transmission standard to which every telephone connection must conform. A typical standard (depending upon the type of exchange) is 1000 Ω for the signalling limit and 10 dB for the transmission limit. The distribution-cable characteristics for each size of cable allow a certain radius to be reached before the limit is reached. For example, a 0·6 mm copper cable has a line resistance of 122 Ω and a planning attenuation of 1·3 dB (at 1600 Hz) per kilometre. The stipulated standards therefore limit the geographical size of a telephone area.

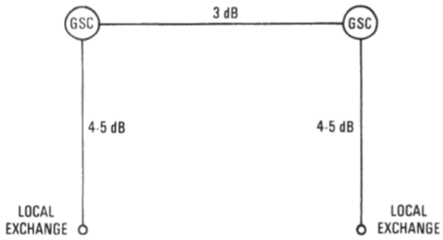
On occasions, there may be a telephone demand just outside the signalling or transmission limits of an exchange. To meet this need, a line extender can be used. Depending on the requirement, the line extender may improve either the line transmission or signalling characteristics sufficient to cater for the excessive losses in the line. The system is useful

for individual lines but would not be so economically attractive on a general basis.

(*c*) The national transmission plan was formulated in the late-1950s when subscriber trunk dialling (STD) was introduced. It enabled planners to ensure:

(*i*) that routings remained within acceptable quality limits, and
(*ii*) that the overall transmission performance was acceptable on all calls over different classes of circuit.

The transmission limits encountered on a trunk call routed directly between two GSCs are shown in the sketch.



Q7 (*a*) *Define the term 'project investment life' and state the annual running costs that are expressed as annual charges.*

(*b*) *Define the term 'net recovery value'.*

(*c*) *Explain how a 'sinking fund' can be initiated to counter the effects of plant depreciation.*

(*d*) *The comparative capital cost (CCC) of a call connect system is £5000. If the net recovery value is 10% of the CCC over its 10-year life and the sinking fund deposit factor is 0·070, estimate the depreciation annual charge of the equipment.* (*20 min*)

A7 (*a*) When a project worthy of capital investment is considered, the first step in the assessment of long-term costs is to decide the period over which the costs are to be compared. This period is called the *investment life*, and depends on the nature of the project.

A project consists initially of a capital cost followed by 'running costs'; these form the basis of 'annual charges', which are assessed under the following headings:

(*i*) interest payment on capital,
(*ii*) depreciation of plant,
(*iii*) maintenance charges, and
(*iv*) operating costs.

(*b*) Net recovery value is the value of the plant upon the final recovery, or scrap as a saleable item, less the cost of its recovery. The recovery costs include labour and the freight and handling, plus the appropriate indirect costs.

(*c*) Plant is assumed to suffer a progressive loss in value from the beginning of its life to the average net recovery at the end. This loss may be accounted for by annual payments into an account known as the *sinking fund*. The fund is then assumed to attract interest at the estimated minimum interest rate.

(*d*) The depreciation annual charge is calculated as follows:

depreciation annual charge

$$= \text{fund deposit factor} \times (\text{CCC} - 10\%\ \text{CCC}),$$
$$= 0{\cdot}070 \times (5000 - 500),$$
$$= \underline{£315}.$$

Q8 (*a*) *Explain what is meant by the term 'radial overhead' distribution.*

(*b*) *State the advantages of radial overhead distribution over an underground feed on housing estates.*

(*c*) *Despite the advantages of radial overhead distribution, underground feed is often used in practice on housing developments. Explain why this is so.*

(*d*) *Describe the frontage-tee method of service feed. Explain, with the aid of a sketch, how, by the use of unallocated pairs in the cable, a tenancy can be given a second line without the need to open up a tee joint.* (*25 min*)

A8 (*a*) It is generally cheaper to use overhead distribution rather than underground distribution, and this usually makes it the first-choice method of distribution to a customer's premises.

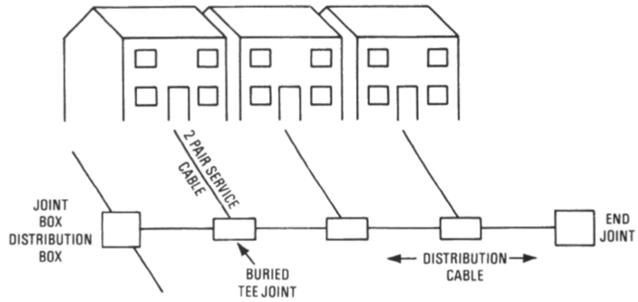
For a 'radial overhead' method of distribution, an underground cable is run from a cross-connection point to terminate at a distribution-point terminal box at the top of a pole. Dropwires are then led out of the box to radially serve individual installations surrounding the pole; this leads to the term of distribution being known as *radial overhead*.

(*b*) The main advantages of radial overhead over an underground feed are:

(*i*) easy to install,
(*ii*) cheaper to install,
(*iii*) easier to maintain,
(*iv*) provides for a more convenient testing point, and
(*v*) better distribution flexibility, especially when the catchment area for a distribution point has a penetration figure of less than one.

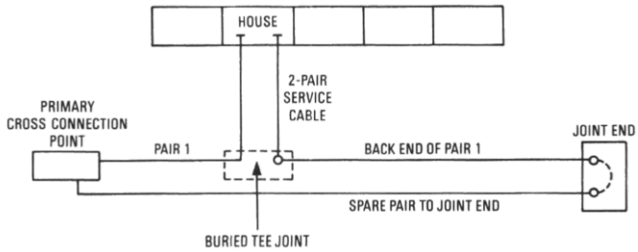
(*c*) Underground feeds are often provided as an alternative to overhead feeds because of the displeasing visual effect of overhead feeds.

(*d*) In the frontage-tee system, the customer is served by a two-pair service cable which is laid from the house to an individual joint at the footway, where it is connected into the main distribution cable. This is illustrated in sketch (*a*).



(*a*)

The individual tee joints are buried and therefore somewhat inconvenient for access. As an alternative to gaining access to every individual buried joint (such as in the event of a fault condition), the second pair is connected to the back end of the telephone feed pair of the distribution cable at the time of the initial installation. This means that there is a pair running from the customer's premises to the joint end, as shown in sketch (*b*).



(*b*)

For frontage-tee distribution cables, any pairs not allocated to specific addresses can be made available over the whole length of the cable. By this means, tenancy spare pairs can be connected at the easily accessible joint end of the cable to provide for a second connection for any tenancy, without the need to open up a tee joint.

Q9 (*a*) *With reference to the Telecommunications Act—Telecommunications Code—explain the term 'statutory undertaker'.*

(*b*) *If the right to place plant in the public highway is invested within a parliamentary statute, explain the purpose of the Public Utilities and Street Works Act, 1950. State how the purpose of this act differs in principle to the Highways Act, 1981.*

(*c*) *State the employer's liability in the event of an injury to a third party caused by the carelessness of one of it's employees during working hours. Illustrate your answer with an example and suggest a circumstance of exception.* (*25 min*)

A9 (*a*) Under the Telecommunications Code, businesses may apply, to the Secretary of State, for a licence to provide public communications services. On the granting of such a licence, the holder then has a 'statutory' right (that is, a right under law), to go onto the public highway and place plant.

It is the terms of the licence that will stipulate any conditions to which the holder must conform. The licence holder is termed a *statutory undertaker*. The term is defined as an undertaker specifically mentioned in a statute, such as the Telecommunications Act.

(*b*) Although the statute authorises the undertaker to place plant in the public highways, the Public Utilities and Street Works Act (PUSWA) controls the procedure in which the plant is actually laid. The PUSWA

differs from the Highways Act in that it may deal with new plant, whereas the Highways Act affects only plant already *in situ*.

(*c*) An employer is not exempt from the actions of its employees during employment. If an employee is negligent, causing a third party to suffer, then that third party has the right to sue the employee. However, although the employee is liable, the injured party would also have the right to sue the employer direct and would be more likely to do so as the employer is the more substantial defendant. But, the employer would be able to seek compensation for its own loss from the negligent employee.

An example where negligence on the behalf of the employee can cause an accident is failing to adequately safeguard a working site excavation.

A circumstance of exception is when the rule of 'vicarious liability' arises such as is incurred when an employee acts outside the course of his/her employment. (A typical example would be where an employee leaves his place of employment and, when using an official vehicle for unofficial purposes, an accident occurs.)

Q10 *(a) State the relationship between pressure, gas mass flow and pneumatic resistance in a gas pressurised cable.*

(b) The pneumatic resistance of a 1000-pair PEUT cable of conductor diameter 0·6 mm is 40 mbar h/g km for each 100 pairs. Calculate the rate of air flow under the conditions of maximum leak (zero pressure at the leak), at the far end of a 750 m length if air is applied at 600 mbar at the exchange end.

(c) Define the term 'pneumatic resistivity' of a cable and explain why the pneumatic resistivity of one cable may well vary significantly to another cable even though it is of the same type and size. *(25 min)*

A10 (*a*) A pneumatic analogy of ohm's law may be applied. The pneumatic resistance of a cable is defined as the resistance offered to a steady mass flow of gas caused by the pressure difference along the length of the cable.

If R_{pm} = pneumatic resistance,

Q_m = rate of gas mass flow in grammes per hour (g/h), and

ΔP = pressure difference along the length of the cable,

then, applying the Ohm's law analogy:

$$Q_m = \frac{\Delta P}{R_{pm}}.$$

(*b*) For the cable given:

$$\Delta P = (600 - 0) = 600\,\text{mbar},$$

$$R_{pm} = 40 \times \frac{750}{1000}(\text{length}) \times \frac{100}{1000}(\text{pairs}),$$

$$= 40 \times 0{\cdot}75 \times 0{\cdot}1,$$

$$= 3\,\text{mbar h/g km}.$$

And if,

$$Q_m = \frac{\Delta P}{R_{pm}},$$

then,

$$Q_m = \frac{600}{3},$$

$$= \underline{200\,\text{g/h}}.$$

(*c*) Pneumatic resistivity is

the pneumatic resistance of the cable
× the unit cross-sectional area of its sheath per unit length.

Different values can be obtained from one cable to another of the same type and size owing to

(*i*) tighter packing of conductors,
(*ii*) varying insulation, and
(*iii*) variation of manufactures.

Questions and answers contributed by R. C. Harris

BTEC: MATHEMATICS (2) II

The following set of questions with answers covers the range and levels of questions that a student may expect to encounter following the BTEC half unit Mathematics (2)II. Students are advised to read the notes on p. 1

Q1 *(a) Solve the following equations for x:*

(i) $3\log 2x - \log 2x = \log 3x - \log 25$, and
(ii) $\log(x+1) + \log(x-1) = 2\log(x-3)$.

(b) Evaluate

$$\frac{\log 25 - \log 125 + 2\log 5}{3\log 5}.$$

(c) Simplify

$$\frac{\log 125 + \frac{1}{3}\log 8}{\frac{3}{4}\log 81}.$$

(30 min)

A1 (*a*) (*i*) $3\log 2x - \log 2x = \log 3x - \log 25.$

From the laws of logarithms, $3\log 2x = \log(2x)^3$. Therefore, the equation becomes

$$\log\left\{\frac{(2x)^3}{2x}\right\} = \log\left\{\frac{3x}{25}\right\}.$$

Taking the antilog of both sides of the equation gives

$$\frac{8x^3}{2x} = \frac{3x}{25}.$$

$$\therefore \quad \frac{8x^3}{6x^2} = \frac{1}{25}.$$

$$\therefore \quad \frac{4}{3}x = \frac{1}{25}.$$

$$\therefore \quad x = \frac{3}{100},$$

$$= \underline{0{\cdot}03}.$$

(*ii*) $\log(x+1) + \log(x-1) = 2\log(x-3).$

$$\therefore \quad \log(x+1) + \log(x-1) = \log(x-3)^2.$$

$$\therefore \quad \log\{x+1)(x-1)\} = \log(x-3)^2.$$

Taking the antilog of both sides of the equation gives

$$(x+1)(x-1) = (x-3)^2.$$

$$\therefore \quad x^2 - 1 = x^2 - 6x + 9.$$

$$\therefore \quad 6x = 10.$$

$$\therefore \quad x = \underline{1\frac{2}{3}}.$$

(*b*)
$$\frac{\log 25 - \log 125 + 2\log 5}{3\log 5}$$

$$= \frac{\log\left\{\frac{25 \times 5^2}{125}\right\}}{3\log 5},$$

$$= \frac{\log 5}{3\log 5} = \underline{\frac{1}{3}}.$$

(c) $$\frac{\log 125 + \dfrac{1}{3}\log 8}{\dfrac{3}{4}\log 81}$$

$$= \frac{\log\{5^3 \times 8^{1/3}\}}{\log(81)^{3/4}},$$

$$= \underline{\frac{\log 250}{\log 27}}.$$

Q2 Given the formula

$$G = \frac{20}{m}\left(1 - \frac{1}{n}\right)\log_e\left(\frac{1}{K}\right),$$

which is to calculate the diversity (G) for (n) receivers, where m and K are constants, calculate G when m = 2·2, n = 5 and K = 0·2 correct to one decimal place. *(10 min)*

A2 Substituting given values for m, n and K in the formula gives

$$G = \frac{20}{2{\cdot}2}\left(1 - \frac{1}{5}\right)\log_e\left(\frac{1}{0{\cdot}2}\right).$$

$$\therefore \quad G = 9{\cdot}09 \times 0{\cdot}8 \times \log_e 5.$$

$$\therefore \quad G = 7{\cdot}272 \times 1{\cdot}6094.$$

$$= \underline{11{\cdot}7} \text{ (correct to one decimal place).}$$

Q3 Solve the simultaneous equations

$$2(x + y) = xy, \text{ and} \qquad \ldots\ldots(1)$$

$$2x - y = 9, \qquad \ldots\ldots(2)$$

for x and y. *(30 min)*

A3 Rearranging equation (2) to make x the subject of the equation gives

$$2x = 9 + y.$$

$$\therefore \quad x = \frac{9 + y}{2} \qquad \ldots\ldots(2a)$$

Substituting for x in equation (1) gives

$$2\left(\frac{9 + y}{2} + y\right) = \left(\frac{9 + y}{2}\right)y.$$

Solving for y gives

$$9 + y + 2y = 4\frac{1}{2}y + \frac{1}{2}y^2.$$

Collecting terms gives

$$\frac{1}{2}y^2 + \frac{3}{2}y - 9 = 0.$$

Multiplying through by 2 gives

$$y^2 + 3y - 18 = 0.$$

Factorising gives

$$(y + 6)(y - 3) = 0.$$

$$\therefore \quad y = -6 \text{ or } 3.$$

Therefore, from equation (2a)

when $y = -6$, $x = \dfrac{9 - 6}{2} = 1\frac{1}{2}$, and

when $y = 3$, $x = \dfrac{9 + 3}{2} = 6.$

These answers can be checked by substituting in equation (1).

When $x = 1\frac{1}{2}$ and $y = -6$,
left-hand side $= 2 \times (1\frac{1}{2} - 6) = -9$, and
right-hand side $= 1\frac{1}{2} \times (-6) = -9$.
Therefore, $\underline{y = -6, x = 1\frac{1}{2}}$ is a possible solution.
When $x = 6$ and $y = 3$,
left-hand side $= 2 \times (6 + 3) = 18$, and
right-hand side $= 6 \times 3 = 18$.
Therefore, $\underline{x = 6, y = 3}$ is a possible solution.

Q4 Fig. 1 shows the cross-section of a building which is 25 m long and has a volume of 2700 m³. Its cross-section is a rectangle surmounted with a semicircular roof. The maximum height is 12 m and its width is 2x metres. Form the equation

$$x^2(4 - \pi) - 48x + 216 = 0,$$

and hence find the width of the building correct to two decimal places. *(45 min)*

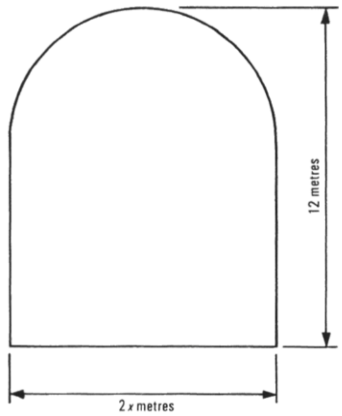


Fig. 1

A4

$$\text{Volume} = \left\{\frac{\pi x^2}{2} + (12 - x) \times 2x\right\} \times 25.$$

$$\therefore \quad 25\left\{\frac{\pi x^2}{2} + (12 - x) \times 2x\right\} = 2700.$$

$$\therefore \quad \frac{\pi x^2}{2} + 24x - 2x^2 = \frac{2700}{25}.$$

$$\therefore \quad \pi x^2 + 48x - 4x^2 = \frac{5400}{25}.$$

$$\therefore \quad \pi x^2 + 48x - 4x^2 = 216.$$

$$\therefore \quad \underline{x^2(4 - \pi) - 48x + 216 = 0.}$$

By using the formula method to solve the equation,

$$x = \frac{+48 \pm \sqrt{\{48^2 - 4 \times 216(4 - \pi)\}}}{2(4 - \pi)},$$

$$= \frac{+48 \pm \sqrt{(2304 - 741{\cdot}664)}}{1{\cdot}717},$$

$$= \frac{48 \pm 39{\cdot}526}{1{\cdot}717},$$

$$= \frac{87{\cdot}526}{1{\cdot}717} \text{ or } \frac{8{\cdot}474}{1{\cdot}717},$$

$$= 50{\cdot}98 \text{ or } 4{\cdot}94, \text{ correct to two decimal places.}$$

Checking the answers in the original equation, first for $x = 50{\cdot}98$, gives

$$50{\cdot}98^2(4 - \pi) - 48 \times 50{\cdot}98 + 216,$$

$$= 2598{\cdot}96 \times 0{\cdot}858 - 2447{\cdot}04 + 216,$$

$$= 2229{\cdot}91 - 2447{\cdot}04 + 216,$$

$$\approx 0.$$

$\therefore \quad x = 50{\cdot}98$ is a solution.
Substituting for $x = 4{\cdot}93$ gives

$$\begin{aligned} &4{\cdot}94^2(4-\pi) - 48 \times 4{\cdot}94 + 216,\\ &= 24{\cdot}40 \times 0{\cdot}858 - 237{\cdot}12 + 216,\\ &= 20{\cdot}94 - 237{\cdot}12 + 216,\\ &\approx 0.\end{aligned}$$

$\therefore \quad x = 4{\cdot}93$ is a solution.
Therefore, the width of the building is

$$2 \times 4{\cdot}94 = 9{\cdot}88\,\text{m, or}$$

$$2 \times 50{\cdot}98 = 101{\cdot}96\,\text{m}.$$

However, with a total height of 12 m, the only practical answer is a width of 9·86 m.

Q5 *Solve the following equations for x:*
(a) $x^{0\cdot75} = 42,$
(b) $3{\cdot}8^x = 62,$
(c) $7{\cdot}4^{2\cdot6} = x,$
(d) $e^x = 10{\cdot}6,$ *and*
(e) $e^{7\cdot2} = x.$ *(30 min)*

A5 *(a)* $x^{0\cdot75} = 42.$
Taking logarithms to base 10 of both sides of the equation gives

$$0{\cdot}75\log_{10}x = \log_{10}42.$$

$$\therefore \quad \log_{10}x = \frac{\log_{10}42}{0{\cdot}75},$$

$$= \frac{1{\cdot}623}{0{\cdot}75},$$

$$= 2{\cdot}164.$$

$$\therefore \quad x = 145{\cdot}88.$$

(b) $3{\cdot}8^x = 62.$
Taking logarithms to base 10 of both sides of the equation gives

$$x\log_{10}3{\cdot}8 = \log_{10}62.$$

$$\therefore \quad x = \frac{\log_{10}62}{\log_{10}3{\cdot}8},$$

$$= \frac{1{\cdot}7924}{0{\cdot}5798},$$

$$= 3{\cdot}09.$$

(c) $7{\cdot}4^{2\cdot6} = x.$
Taking logarithms to base 10 of both sides of the equation gives

$$2{\cdot}6\log_{10}7{\cdot}4 = \log_{10}x.$$

$$\therefore \quad 2{\cdot}6 \times 0{\cdot}8692 = \log_{10}x.$$

$$\therefore \quad \log_{10}x = 2{\cdot}26.$$

$$\therefore \quad x = 182.$$

(d) $e^x = 10{\cdot}6.$
Taking logarithms to base e of both sides of the equation gives

$$x\log_e e = \log_e 10{\cdot}6.$$

$$\therefore \quad x = \log_e 10{\cdot}6. \quad [\log_e e = 1.]$$

$$= 2{\cdot}361.$$

(e) $e^{7\cdot2} = x.$
Direct from a calculator, $x = e^{7\cdot2} = 1339{\cdot}4.$
Or, Taking logarithms to base e of both sides of the equation gives

$$7{\cdot}2\log_e e = \log_e x.$$

$$\therefore \quad \log_e x = 7{\cdot}2.$$

$$\therefore \quad x = 1339{\cdot}4.$$

Q6 *Differentiate with respect to x*
(a) $y = 2x^2$, *from first principles; and*
(b) *(i)* $y = 4x^3 - 3x^2 + 6x - 2$, *and*
(ii) $y = 4\cos x - 5\sin x$ *by using the differentiation rules.* *(20 min)*

A6 *(a)* $y = 2x^2.$

Let x increase by a small amount δx. Therefore, y will increase by a small amount δy.

$$\therefore \quad y + \delta y = 2(x + \delta x)^2.$$

Expanding right-hand side of equation gives

$$y + \delta y = 2\{x^2 + (2x\delta x) + (\delta x)^2\}.$$

$$\therefore \quad y + \delta y = 2x^2 + (4x\delta x) + 2(\delta x)^2.$$

Subtracting $y = 2x^2$ gives

$$\delta y = (4x\delta x) + 2(\delta x)^2.$$

Dividing through by δx gives

$$\frac{\delta y}{\delta x} = \frac{4x\delta x}{\delta x} + \frac{2(\delta x)^2}{\delta x}.$$

$$\therefore \quad \frac{\delta y}{\delta x} = 4x + 2\,\delta x.$$

Let $\delta x \to 0$. Then, in the limit,

$$\frac{\delta y}{\delta x} \to \frac{dy}{dx}.$$

Therefore, $\delta y/\delta x$ becomes dy/dx and $2\delta x$ becomes 0.

$$\therefore \quad \frac{dy}{dx} = 4x.$$

(b) *(i)* $y = 4x^3 - 3x^2 + 6x - 2.$

$$\therefore \quad \frac{dy}{dx} = 12x^2 - 6x + 6.$$

(ii) $y = 4\cos x - 5\sin x.$

$$\therefore \quad \frac{dy}{dx} = -4\sin x - 5\cos x.$$

$$= -(4\sin x + 5\cos x).$$

Q7 *(a) If θ is small find an approximation for the expression*

$$\frac{\tan 4\theta}{1 - \cos 2\theta}.$$

(b) Sketch the graphs of
(i) $y = \sin^2 \omega t$, *and*
(ii) $y = \cos^2 \omega t$,
for values of t between 0 and 2π/ω. *(20 min)*

A7 *(a)* $\dfrac{\tan 4\theta}{1 - \cos 2\theta}.$

If θ is small, then $\tan 4\theta \approx 4\theta$, and

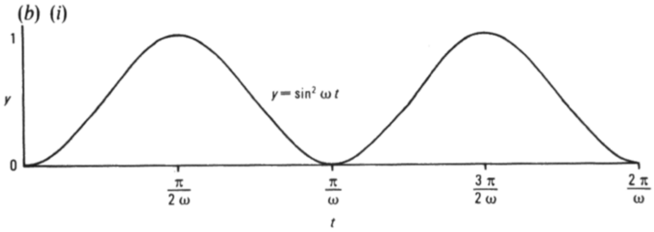
$$\cos 2\theta \approx 1 - 2\frac{(2\theta)^2}{2}.$$

Therefore, if θ is small,

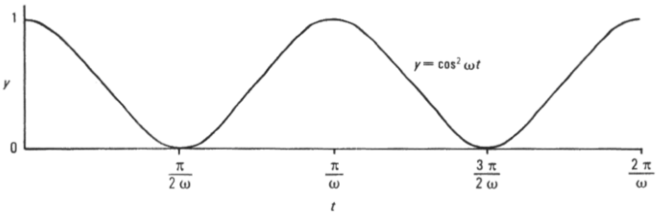
$$\frac{\tan 4\theta}{1 - \cos 2\theta} \approx \frac{4\theta}{1 - \left\{1 - \frac{(2\theta)^2}{2}\right\}},$$

$$= \frac{4\theta}{\frac{4\theta^2}{2}} = \frac{8\theta}{4\theta^2} = \frac{2}{\theta}.$$

(b) *(i)*



(*ii*)



Q8 (*a*) *On the same axes and using the same scale, draw the graphs of* $y = \sin^2\theta$ *and* $y = 2\cos\theta$ *for values of* θ *from 0 to 180° at intervals of 30°.*

(*b*) *By adding ordinates of the two curves draw the resultant graph of* $y = \sin^2\theta + 2\cos\theta$.

(*c*) *State the amplitude of the resultant graph.* (*35 min*)

A8 (*a*) The tables of values are as follows:

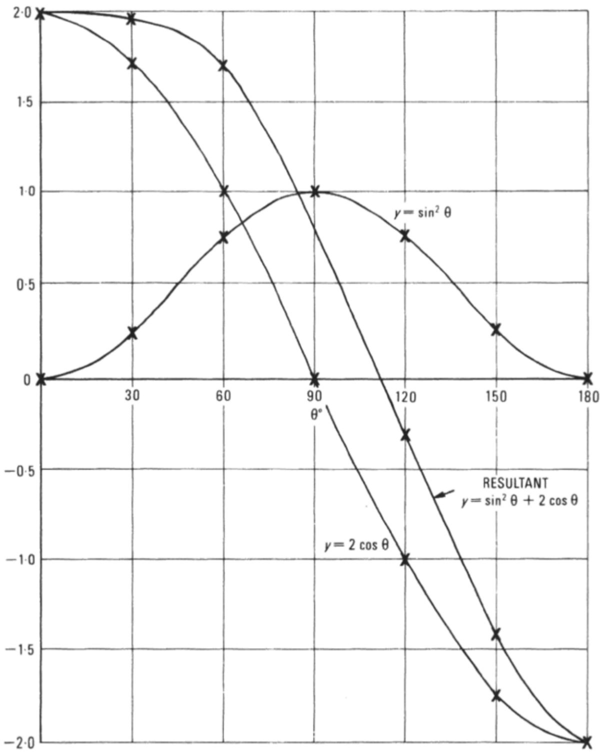
$\theta°$	0	30	60	90	120	150	180
$\sin\theta$	0	0·5	0·866	1	0·866	0·5	0
$\sin^2\theta$	0	0·25	0·75	1	0·75	0·25	0

$\theta°$	0	30	60	90	120	150	180
$\cos\theta$	1	0·866	0·5	0	−0·5	−0·866	−1
$2\cos\theta$	2	1·732	1	0	−1	−1·732	−2

The graphs are shown in the sketch.

(*b*) Adding ordinates gives the following:

$\theta°$	0	30	60	90	120	150	180
$\sin^2\theta + 2\cos\theta$	2	1·982	1·75	1	−0·25	−1·482	−2



The resultant graph is also shown in the sketch.

(*c*) From the graph, the amplitude is approximately 2.

Questions and answers contributed by T. R. Sands

BTEC: TELEPHONE SWITCHING SYSTEMS III

The questions in this paper are based on the BTEC's standard unit U81/745. Students are advised to read the notes on p. 1

Q1 *In a 5-digit non-director Strowger telephone exchange, the grade of service at each switching stage is 0·005. What would be the approximate overall grade of service on an own exchange call?* (*3 min*)

A1 The switching stages and the grades of service at each stage are as follows:

Subscriber's uniselector	0·005
Group selector 1	0·005
Group selector 2	0·005
Group selector 3	0·005
Final selector	

The approximate overall grade of service is

$$4 \times 0{\cdot}005 = 0{\cdot}02.$$

Q2 *An automatic traffic recorder is connected to a switching stage in the busy hour and registers the following numbers of engaged circuits at six successive readings: 12, 14, 14, 9, 11 and 12. Calculate the traffic intensity.* (*3 min*)

A2 The traffic intensity

$$= \frac{12 + 14 + 14 + 9 + 11 + 12}{6} = \frac{72}{6} = \underline{12 \text{ erlangs.}}$$

Q3 *Explain the purpose of the signal conversion circuit used in the stored-program control (SPC) equipment of in Strowger director exchanges.* (*3 min*)

A3 The signal conversion circuit is an interface between the Strowger exchange and the computer-like processor, and provides

(*a*) change of voltage levels, and

(*b*) temporary storage to allow different operating speeds to be matched.

Q4 *A non-director telephone exchange area is made up as follows:*

Main	*4500 lines*
Satellite A	*2500 lines*
Satellite B	*2000 lines*

State:

(*a*) *the type of numbering scheme used,*

(*b*) *the typical numbers allocated, and*

(*c*) *the main advantage of a multi- over a single-exchange area.* (*8 min*)

A4 (*a*) Linked numbering scheme.

(*b*)

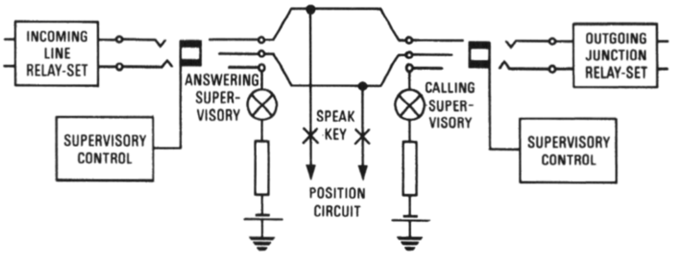
Main	21 000–25 999
Satellite A	31 000–33 499
Satellite B	41 000–42 999

[*Tutorial note:* The second digit of the first number in each range is 1 rather than 0 to save wear on the switch.]

(*c*) Saving in line plant with the shorter local lines.

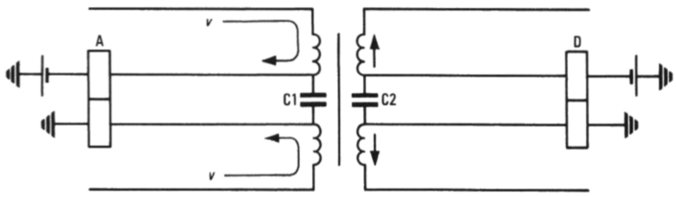
Q5 (*a*) *Give a reason why an operator on an assistance sleeve-control switchboard would need to extend a call from a calling customer.*
(*b*) *Draw a block diagram showing how such a call is extended.* (*8 min*)

A5 (*a*) For calls that cannot be completed by direct dialling or where a caller is unable to complete the call for any other reason.
(*b*)



Q6 (*a*) *Explain, with the aid of a simple diagram, how a transformer-type transmission bridge reduces the distortion of dial pulses on tandem links.*
(*b*) *Name two other advantages of the transformer bridge as compared with the capacitor type.* (*8 min*)

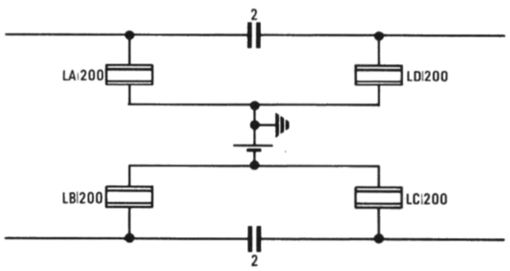
A6 (*a*) See sketch. Longitudinal voltage surges (v) are cancelled by the differential action of the transformer.



(*b*) Two advantages of a transformer bridge over a capacitor bridge are:
(*i*) normal-type relays, rather than high-impedance relays, can be used; and
(*ii*) the frequency/attenuation response is more linear over the normal speech-frequency range (300 Hz–3·4 kHz).

Q7 *Draw the circuit elements of the Stones transmission bridge and list its advantages and disadvantages.* (*10 min*)

A7



Advantages
(*a*) Simple and compact.
(*b*) Relatively cheap.
(*c*) Relays can be used for signalling purposes.

Disadvantages
(*a*) High-impedance relays are necessary.
(*b*) Not suitable on tandem links because of pulse distortion.
(*c*) Non-linear frequency/attenuation characteristics.

Q8 (*a*) *Explain the advantages of call queueing compared to random servicing from an operator, both from the point of view of the customer and the company.*
(*b*) *For a single queue system, state the range of mathematical probability of a caller having to wait for an answer.* (*5 min*)

A8 (*a*) With random servicing, a customer may be ignored while others calling later are answered first. In a queueing system, calls are answered in an orderly fashion; for example, first come, first served. From a company's point of view, a caller may well give up waiting, resulting in lost traffic and lost revenue.
(*b*) 0–1.

Q9 (*a*) *List the functions of the distributor in a typical call queueing system to a manual switchboard.*
(*b*) *Give the operating procedure for extracting a call from the queue.* (*5 min*)

A9 (*a*) The functions of the distributor are:
(*i*) to return ringing tone to the caller once in the queue,
(*ii*) to allocate the caller to the next place in the queue,
(*iii*) to extend the caller to an operator, and
(*iv*) to return engaged tone to a caller when the queue is full.

(*b*) Operate SPEAK key of a free connecting circuit and depress the CONNECT ANSWER bar.

Q10 *State what you understand by the term 'inband signalling', and give one disadvantage of inband signalling compared with outband signalling.* (*5 min*)

A10 With inband signalling, all of the signalling frequencies are within the speech range of 300–3400 Hz and can, therefore, be used only when speech transmission is not taking place. The main disadvantage of such a system is that some form of voice guard circuit is necessary to prevent false operation of the signalling equipment by the signalling frequency when produced by the voice.

Q11 *Explain how the various time lengths of the single signalling frequency provide for various signalling conditions in the AC9 system. Also give the reason for the choice of frequency used.* (*8 min*)

A11 Signalling conditions are provided as follows:
(*a*) *Circuit seized* calling loop causes 65 ms tone.
(*b*) *Pulsing* loop-disconnect pulses are converted to 60 ms pulses of tone.
(*c*) *Called customer answers* the line reversal is converted to 250 ms of tone.
(*d*) *Called customer clears* the removal of the line reversal causes 250 ms of tone to be returned.
(*e*) *Calling customer clears* the removal of the loop causes the outgoing relay-set to send 900 ms of tone to the incoming relay-set, which disconnects the loop to the distant exchange. The incoming relay-set then transmits 1000 ms of tone to the outgoing relay-set; that is, the *release guard* signal.

A signalling frequency of 2280 Hz was chosen because it is seldom produced by the voice and, when it is, it is at a low level, it exists normally only for very short periods, and it is accompanied by other frequencies, thus allowing a guard circuit to be used.

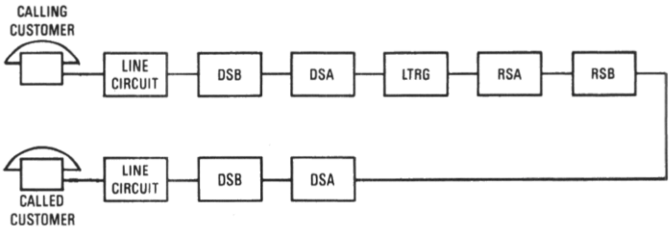
Q12 *Two forms of alternating current signalling used in the telecommunications network are single-frequency and multi-frequency. State, for each type, whether they are inband or outband systems.*
Give the main advantage of multi-frequency signalling over single-frequency and describe how this advantage is achieved. (*10 min*)

A12 Both types of signalling are inband; that is, the signalling frequency/frequencies used are within the normal voice range of 300 Hz to 3·4 kHz.
With multi-frequency signalling, a considerable increase in signalling speed is possible. In the case of single-frequency working, each digit is controlled by the speed of the dial. With multi-frequency working, a pair of frequencies are sent for a short duration of time and are made to represent an actual digit. A simple two-out-of-five code is tabulated below to show how the digits 1 to 0 can be signalled with frequencies f_1 to f_5.

Digit	Frequencies	Digit	Frequencies
1	f_1 and f_2	6	f_2 and f_4
2	f_1 and f_3	7	f_2 and f_5
3	f_1 and f_4	8	f_3 and f_4
4	f_1 and f_5	9	f_3 and f_5
5	f_2 and f_3	0	f_4 and f_5

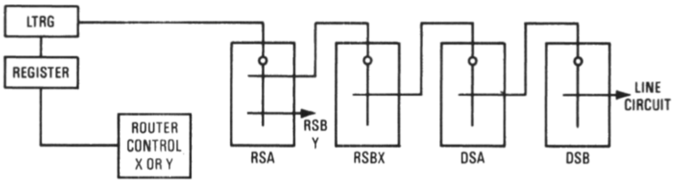
Q13 *Draw a trunking diagram to show an established own-exchange call on a TXK1 crossbar telephone exchange.* (*5 min*)

A13



Q14 Explain, with the aid of a trunking diagram, how a call is routed from the transmission relay group to the wanted subscriber in a TXK1 crossbar telephone exchange. (*20 min*)

A14 As shown in the sketch, the call is extended from the line transmission relay group (LTRG) to the called customer via the router and the distributor to which the called customer's line is connected.



The register is connected to the router control which, in turn, is connected to the line marker. The marker returns an *acknowledge* signal and the router control then extends the necessary signals for the called customer's number. The subscriber's line circuit and associated DSB outlet is inspected to allow testing and marking to take place. If the outlet is free, the DSB is instructed to mark all free links to the DSAs, and this sets up the auxiliary and select magnets in the available DSAs. Marking signals from the DSA are confined to the X or Y RSBs of the router setting up the call. Each RSB that receives a mark sets up the magnet combinations and then sends marks to the RSAs. Only one RSA is conditioned to receive a mark; that is, the one which is connected to the LTRG being used. When the RSA receives a mark, it signals to inform the router control that a path is available. The router control then applies an earth to the P-wire via the register and the LTRG to operate the bridge magnet in the RSA. Closure of this crosspoint extends the earth to operate the bridge magnets in the RSB, DSA and DSB in succession to close the points and complete the connection.

All common-control equipment is released and the LTRG takes over the call supervision.

Q15 Explain what is meant by

(*a*) *pure-chance traffic, and*
(*b*) *smooth traffic,*

and give an example where each would be expected to be found in a telephone-exchange switching system. (*8 min*)

A15 (*a*) Pure-chance traffic is when calls are as likely to originate at one moment as at any other. This exists only where traffic originates from an infinite number of sources. In practice, the number of sources is large compared with the number of simultaneous calls, and so the term *pure-chance traffic* is acceptable.

(*b*) Smooth traffic is the term given to traffic on a group of circuits that does not differ greatly from the mean traffic measured over a period of time. Smooth traffic conditions apply when

(*i*) the source is small and the traffic is large, and
(*ii*) at a stage of switching where peaks of originating traffic have been spread over several groups.

An example of pure-chance traffic is that from subscribers' line circuits to the next stage of switching. Smooth traffic would exist after traffic has been concentrated; for example, later group-selector stages or matrix stages.

Q16 (*a*) *Name four reasons why auto-manual switchboards are still necessary within the telecommunications network.*
(*b*) *State two types of switchboard currently in use.* (*5 min*)

A16 (*a*) Any four from:

(*i*) calls that cannot be completed by direct dialling,
(*ii*) assistance calls,
(*iii*) ancillary services,
(*iv*) general enquiries and faults,
(*v*) directory enquiries, and
(*vi*) emergencies.

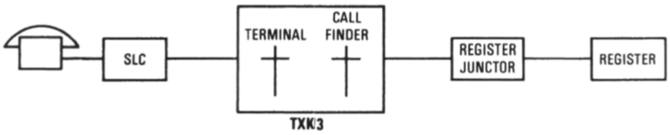
(*b*) Sleeve-control and cordless switchboards.

Q17 When a call is originated in a TXE2 electronic telephone exchange, a relay-set must be seized. Explain how the caller is connected to the correct type of relay-set. (*5 min*)

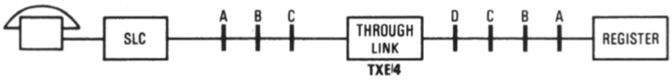
A17 An own-exchange or outgoing relay-set are the choices. The relay-set first seized depends upon the traffic distribution. If the majority of calls are outgoing, then an outgoing relay-set is the first choice. When the common-control equipment recognises an own-exchange call, the original connection to the relay-set is cleared down and a new one set up to an own-exchange relay-set. This is done during the inter-digit pause.

Q18 Name two other systems that can be used to replace a Strowger director exchange. Draw simplified trunking diagrams of these to show a call set up to the point of receiving dial tone. (*15 min*)

A18 TXK3 crossbar (see sketch (*a*)) and TXE4 electronic (see sketch (*b*)) exchange systems.



(*a*)



(*b*)

Q19 Explain the purpose of a through link in a TXE4 electronic telephone exchange, and state why such a circuit cannot be used in a customer-to-customer connection. (*5 min*)

A19 A through-link circuit is used for any connections through the exchange where a transmission bridge is not required, or where one is provided somewhere else in the connection.

A customer-to-customer call requires a transmission bridge and therefore requires a bridge link circuit.

Q20 State the purpose of the decoder in a TXE2 electronic exchange. (*5 min*)

A20 The calling number is generated as a directory number in a two-out-of-five code. Although this is convenient for storage, at a later stage the code must be converted to an equipment number. This task is performed by the decoder.

Q21 Give the reason for including a D-switch on a terminating call in a TXE2 electronic telephone exchange. (*6 min*)

A21 Only three switching stages are necessary to concentrate the originating traffic to the supervisory relay-set. If, however, incoming concentrated traffic was connected directly to the C-switch on terminating calls, then access to the customers' lines would be restricted and link blocking would be liable. The inclusion of the D-switch provides a far greater access by considerably increasing the number of links.

Q22 Name the two switching units that are used when a call is originated in a TXK3 crossbar telephone exchange and the items of common-control equipment that are taken into use. (*5 min*)

A22 (*a*) Line selection unit—made up from the terminal and call finder switches.

(*b*) Originating group selection unit—made up from primary and secondary switches.

The common-control equipment taken into use when a call is being originated are the register finder, originating register, pre-selection coupler and information paths.

Questions and answers contributed by N. A. Collins

BTEC: LINES II

The following questions in this paper are based on the BTEC's standard unit U81/755. Students are advised to read the notes on p. 1

Q1 *(a) Why is it necessary to have defined parameters of system performance?*
(b) Define 'quality of maintenance' of a telephone system. *(2 min)*

A1 (*a*) Without defined parameters of system performance it would not be possible for a planner to estimate the time required to install a system, estimate the cost of an installation, estimate the labour requirements of any installation and estimate the cost efficiency of the system. It would also not be possible to judge the efficiency of the workforce, the efficiency of the system performance, the efficiency of the equipment used in the system and it would not be possible to judge the quality of service provided.

(*b*) The quality of maintenance is defined as the ratio of all faults reported by customers in a specified year to the average number of telephone stations in service during that year.

Q2 *Explain the need for reliable speech transmission.* *(2 min)*

A2 Reliable speech transmission is necessary in order to ensure that the customer is satisfied that the information he is conveying to the listener is being coherently received and that the noise level is low enough for the listener to hear in comfort.

Q3 *Why is it necessary to limit the switching time of a telephone system?* *(2 min)*

A3 After dialling, the caller will expect to receive ring tone, thus indicating that the called party is being rung. If the delay between the end of dialling and the return of ring tone is excessive, the caller may assume that the call has not been switched correctly and, as a consequence, may abort the call. This results in the switching equipment being used without any resultant income to the telephone company. Furthermore, the public image of the company will suffer if customers assume that the equipment is incapable of switching calls through within reasonable time limits.

Q4 *What factors influence the penetration factor of an urban area?* *(2 min)*

A4 The following factors influence the penetration factor:

(*a*) the general standard of living of the residents,
(*b*) the availability of cable pairs to the area,
(*c*) the local public image of the telephone company, and
(*d*) the type of business; that is, business or residential.

Q5 *Two telecommunication companies each provide a service to the general public.*
Company A has a workforce of several thousand and provides a national service; company B has a workforce of less than 20 and provides a very localised service.
(a) List the corporate objectives of each company.
(b) Compare the problems of staff relations with employees of each company. *(6 min)*

A5 (*a*) The corporate objectives of each company will be identical and are

(*i*) the provision of an efficiently engineered system,
(*ii*) a good return on capital investment,
(*iii*) survival of the company,
(*iv*) good staff relations with employees, and
(*v*) customer satisfaction.

(*b*) Good staff relationships will be more difficult to achieve in Company A because of the size of the workforce and the area they cover. This is because many of the employees are remote from the upper management and it is more likely that a breakdown in communications occurs between employer and employee. To improve the relationships, the employer will need to provide a personnel department to act as an interface between management and employee. This department provides the employee with a means of airing any grievances which he may have about the working conditions and facilities of the company. The department may also assist the employee with personal problems which may or may not be related to his employment. To further off-set the disadvantage of remoteness, Company A would have a means of providing social and sporting activities within the company. These help to generate a feeling of team spirit within the company. By these means the management of Company A achieves corporate objective (*iv*) in part (*a*).

The owner of Company B, because of its size and small area, is more likely to know each employee personally. The owner will be able to take a keen interest in every aspect of the company and will be almost immediately aware of any problems arising from the workforce. Each employee would have direct access to the owner and would be able to assess the company's current performance by simply observing the size of the workload of the workforce. Thus, the feeling of remoteness, as experienced by the employees of a large company, will not manifest itself on the employees of Company B and good staff relations with the employees are more readily achieved by the small company; the prime factor being the attitude of the owner towards each individual employee.

Q6 *List the types of forecasting used in telecommunications.* *(1 min)*

A6 The types of forecast are:

(*a*) rolling forecast,
(*b*) bottom-up forecast,
(*c*) top-down forecast, and
(*d*) complementary forecast.

Q7 *Complete the graph shown in Fig. 1 by drawing the predicted rate of growth/decay up to and including 1995.* *(1 min)*

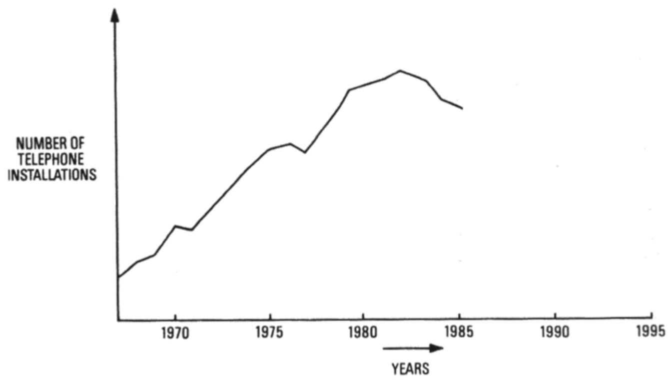
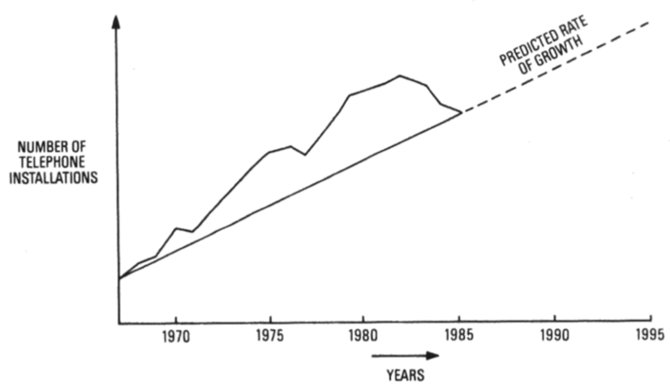


Fig. 1

A7



[*Tutorial Note:* Although the graph shows a steady decline during the period 1983–85, the general trend of the graph is upwards; thus, it may be assumed that the overall trend for the period 1985–95 will also be upwards.]

Q8 The graph shown in Fig. 2 gives the traffic variations of a major telephone exchange in the centre of London plotted on a year-by-year basis. The dotted line indicates the planners' original estimate for the period, based on information available in 1957.

Give typical reasons for the sharp rises in traffic flow displayed on the graph and explain the effects on service to customers because of the actual results not truly following the forecast trend. (*6 min*)

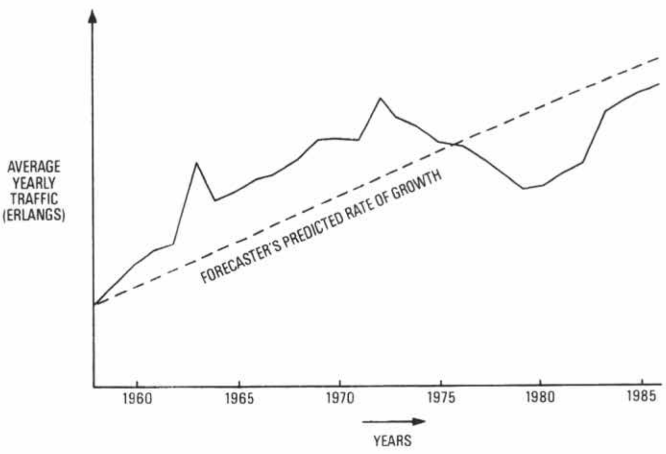


Fig. 2

A8 The sharp increases in traffic flow may have been caused by major international incidents such as a major outbreak of war in the Middle East or the assassination of a major public figure such as the President of the United States of America. In fact any occurrence which may influence the national economy or security would generate a high level of telephone traffic in the City of London. The planner cannot foresee such events and, therefore, is unable to provide customers with the quality of service during these periods.

In 1957 the forecaster would have predicted the future trends of telephone traffic based on to-date figures and predictions of local and national economic growth. The unexpected growth, as shown for the period 1958–74, would have led to a grade of service for the customer below the normal standard and unless short-term remedies were implemented this would have led to a poor public image for the telephone company. The decline in the national economy from 1974–82 is reflected on the graph. During that period the return on capital investment would have been poor as large amounts of switching equipment would have been idle for most of the working day.

Q9 If a cable is extended by an additional length, what effect will this have on

(*a*) *the conductance of the line, and*
(*b*) *the capacitance of the line?* (*1 min*)

A9 (*a*) The line conductance would increase.
(*b*) The line capacitance would increase.

Q10 A cable pair has an inductance of 0·27 mH and a capacitance of 9 nF.

If the resistive and conductive parameters of the cable can be ignored, determine the characteristic impedance of the line. (*2 min*)

A10 The characteristic impedance, Z_0, is given by the expression

$$\sqrt{\frac{L}{C}},$$

where L is the inductance of the line and C is its capacitance.

Substituting the given values

$$Z_0 = \sqrt{\left(\frac{0{\cdot}27 \times 10^{-3}}{9 \times 10^{-9}}\right)},$$

$$= \underline{173\,\Omega}.$$

Q11 What effect does loading have on the characteristic impedance of a cable? (*½ min*)

A11 Loading increases the characteristic impedance of the cable.

Q12 What is the major cause of crosstalk in modern cables? (*½ min*)

A12 Capacitance unbalance.

Q13 Do optical-fibre cables suffer from crosstalk? (*½ min*)

A13 No

Q14 What is the function of a stay attached to a pole? (*1 min*)

A14 The function of a stay is to counteract the bending stresses subjected to the pole by the weight of the wires, the pressure of the wind and the additional weight caused by ice forming on the wires.

Q15 What adverse effect may a stay have on a pole? (*1 min*)

A15 The combined effect of the weight of the lines and the pull of the stay may cause the pole to buckle.

Q16 For the purpose of calculating the required pole and stay strength, would the following wind speeds be regarded as 'normal', 'calm' or 'exceptional'?

(*a*) *98 km/h*
(*b*) *128 km/h* (*1 min*)

A16 (*a*) 98 km/h is regarded as normal, and
(*b*) 128 km/h is regarded as exceptional.

Q17 Which of the following is the best electrical conductor?

(*a*) *Copper,*
(*b*) *silver, or*
(*c*) *aluminium.* (*½ min*)

A17 (*b*) silver

Q18 Explain the term 'temperature coefficient of resistance'. (*2 min*)

A18 The conductivity of any material will change with a change in temperature. This change in conductivity is constant for any given material with any given change in temperature and is referred to as the material's *temperature coefficient*.

When a material's resistance increases with an increase in temperature, the material is said to have a positive temperature coefficient; when a material's resistance falls with an increase in temperature, the material is said to have a negative temperature coefficient.

Generally conductors have a positive temperature coefficient and insulators a negative temperature coefficient. An example of a commonly used conductor with a negative coefficient is carbon.

Q19 Arrange the following planning details in their logical sequence.

(*a*) *Undertake a detailed survey.*
(*b*) *Cost and authorise project.*
(*c*) *Anticipate demand.*
(*d*) *Prepare works instructions and estimate.*
(*e*) *Assess the project and produce a basic plan.*
(*f*) *Prepare preliminary cost estimate for project and enter in programme.* (*2 min*)

A19 (*c*), (*e*), (*f*), (*a*), (*d*), and (*b*).

Q20 What sources are available to the planner when carrying out a map survey of an area? (*1 min*)

A20 Ordnance-survey maps, duct plans, cable plans, local authority plans of proposed road works and proposed development plans.

Q21 What components make up the total cost of a project? (*1 min*)

A21 Operating cost, interest cost, depreciation cost, and maintenance cost.

Q22 State the purpose of a project programme. (*2 min*)

DIGITAL MULTIPLEXING

Contents

This paper was prepared by V. W. Willson, Training Division, British Telecom Local Communications Services.

Supplement to *British Telecommunications Engineering*, Vol. 5, Part 1, April 1986.

INTRODUCTION

To provide digital transmission over British Telecom's network, a family of digital line systems operating at 2, 8, 34, 120 and 140 Mbit/s has been developed. The 2 Mbit/s signal produced by 30-channel pulse-code modulation (PCM) primary multiplex (PMUX) equipment is used as the basic building block of the digital hierarchy. Digital muldex equipment is then used to produce signals at the above bit rates from several 2 Mbit/s signals. The term *muldex* is a contraction of *multiplex* and *demultiplex*, thereby implying both directions of transmission, and is used throughout the following descriptions. On digital muldex equipment, all the inputs and outputs are digital, as distinct from a 30-channel PCM muldex, which is an analogue-to-digital and digital-to-analogue converter.

The various types of digital muldex equipment and their interconnection are shown in Fig. 1.

The equipment can be directly cabled together, which is known as *direct flexibility*, or connected together via a digital distribution frame (DDF).

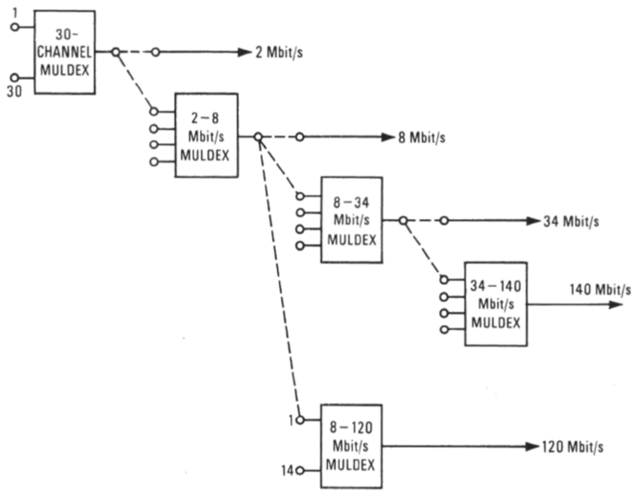


Fig. 1

Terminology

The inputs and outputs on the low-bit-rate side of a muldex are referred to as the *tributaries*, and the high-bit-rate inputs and outputs as the *muldex* (sometimes referred to as *MUX*) *inputs* and *outputs*, as shown in Fig. 2.

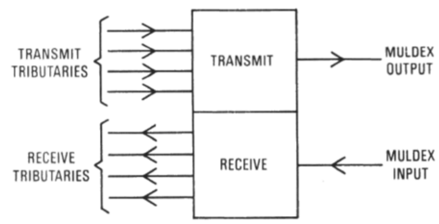


Fig. 2

Muldex Types

Table 1 shows the input and output details of the digital muldex equipment used in the network.

There are optional facilities on the 34–140 Mbit/s muldex which permit tributary inputs at 68 Mbit/s or 34 Mbit/s to be used. The options are:

(*a*) 4 × 34 Mbit/s,
(*b*) 2 × 34 Mbit/s and 1 × 68 Mbit/s, and
(*c*) 2 × 68 Mbit/s.

The 68 Mbit/s signal could be produced by either a hypergroup codec or a television codec.

2–8 Mbit/s MULDEX INPUT SIGNAL

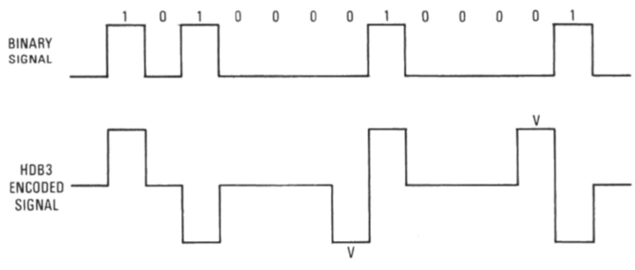
Although the nominal bit rate of the input signal to the 2–8 Mbit/s muldex is 2048 bit/s, a tolerance of 50 parts per million is permitted, resulting in an actual bit rate of 2048 kbit/s ± 102 bit/s. The signal is encoded into high-density bipolar 3 (HDB3) signal with a 50% duty cycle. The 30-channel PCM muldex contains a crystal master oscillator (MO), which determines the output bit rate; the frequency tolerance allows for temperature and ageing effects which cause the MO frequency to drift slightly. Although not significant when PCM is used over audio cable pairs, these frequency errors are very important when digital multiplexing is considered.

HDB3 Coding

The digital signal from the 30-channel PCM muldex is encoded into HDB3, which is the CCITT† standard interface at 2, 8 and 34 Mbit/s. HDB3 is a bipolar signal in which the maximum number of consecutive zeros is restricted to three. To process the digital signal in subsequent equipment, a timing component is extracted from the transmitted digital signal, the amplitude of the signal being proportional to the mark density. By using HDB3, the minimum mark density is two MARKS in any five digit time-slots,which produces a good timing component.

In any sequence of four or more binary 0s, the fourth binary 0 is converted into a MARK having the same polarity as the previous MARK; that is, it is transmitted as a bipolar violation. To eliminate the DC component from the signal, successive violations are of opposite polarity, as shown in Fig. 3. However,

† CCITT—International Telegraph and Telephone Consultative Committee



V: Violation

Fig. 3

TABLE 1

Equipment Type	Number of Tributaries	Tributary Bit Rate (kbit/s)	Muldex Bit Rate (kbit/s)	Equipment Number	
				62 Type	TEP1E
2–8 Mbit/s	4	2 048	85 448	EDM 2401	EDM 6000
8–34 Mbit/s	4	8 448	34 368		EDM 6001
34–140 Mbit/s	4	34 368	139 264		EDM 6002
8–120 Mbit/s	14	8 448	120 000	EDM 2402	

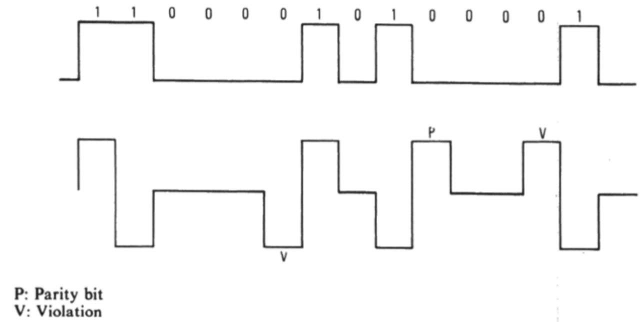


Fig. 4

an even number of MARKS between violations would result in successive violations being of the same polarity. To avoid this, the first 0 of a sequence is changed to a MARK, called the *parity bit*, and the fourth 0 is changed to a MARK which violates the parity bit, as shown in Fig. 4.

GENERAL ASPECTS OF THE 2–8 Mbit/s MULDEX

This paper concentrates, in particular, on describing the principles of operation of the 2–8 Mbit/s muldex; however, these principles can equally well be applied to any muldex. The main features of the muldex are

Transmit Direction

(*a*) to combine the bits from the four input tributaries (interleaving);
(*b*) to insert a frame alignment word (FAW), which enables the signal to be accurately demultiplexed at the receive station;
(*c*) to perform the process, known as *justification*, which is necessary to interleave inputs that are running at slightly different rates;
(*d*) to transmit a distant alarm to the far end in the event of a failure in the system;

Receive Direction

(*e*) to demultiplex the incoming 8448 kbit/s signal into four 2048 kbit/s outputs (disinterleaving);
(*f*) to extract and monitor the FAW;
(*g*) to interpret justification signals from the distant transmit muldex; and
(*h*) to display distant alarm conditions.

Interleaving

The four tributaries are interleaved on a bit-by-bit basis, as this results in minimising the storage required within the muldex. The principle of bit interleaving is shown in Fig. 5; this assumes that all four tributaries are running at exactly the same speed and in phase.

If T is the duration of one bit of the incoming tributaries, each tributary is accessed for a time $T/4$, resulting in the data on the four inputs being present in the time T on the output.

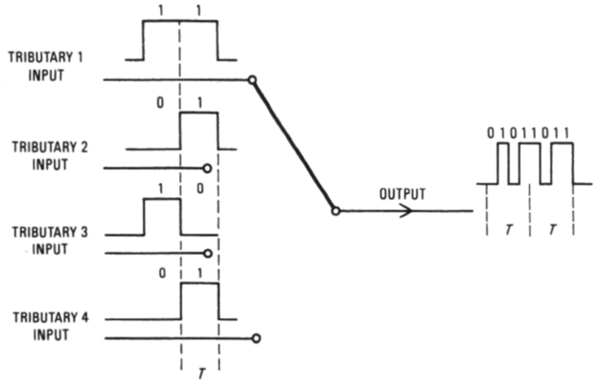


Fig. 5

Frame Structure

To perform the functions mentioned earlier, the muldex goes through a cycle of operations called a *frame*, the structure of which is shown in Fig. 6. Each individual box on the diagram represents one bit in the 8 Mbit/s output signal.

The 2–8 Mbit/s muldex frame is subdivided into four equal sets, each of 212 bits. At a bit rate of 8448 kbit/s, the duration of the frame is:

$$\frac{848}{8448 \times 10^3} = 100 \cdot 38\ \mu s,$$

which corresponds to a frame rate of 9962 Hz.

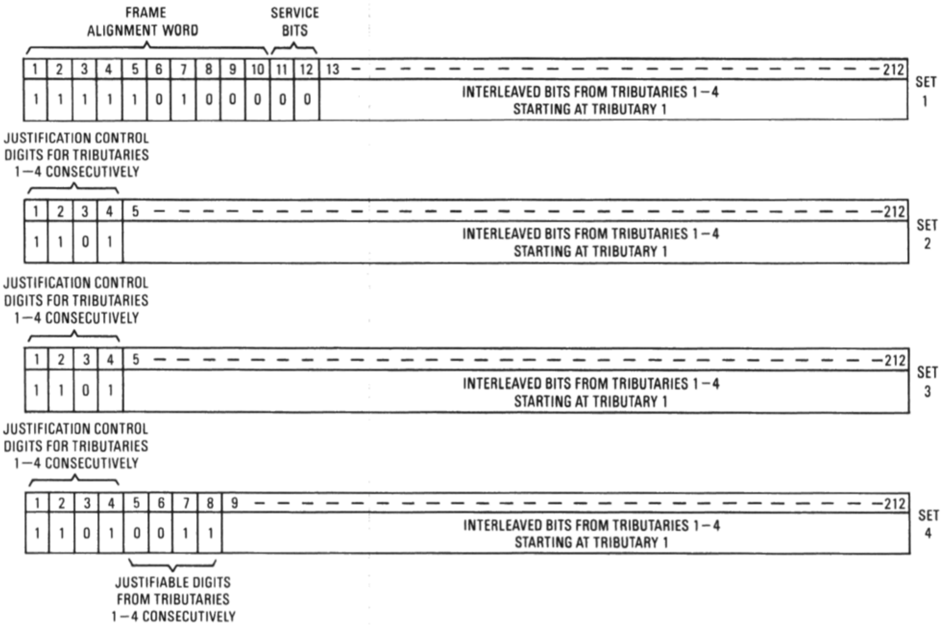
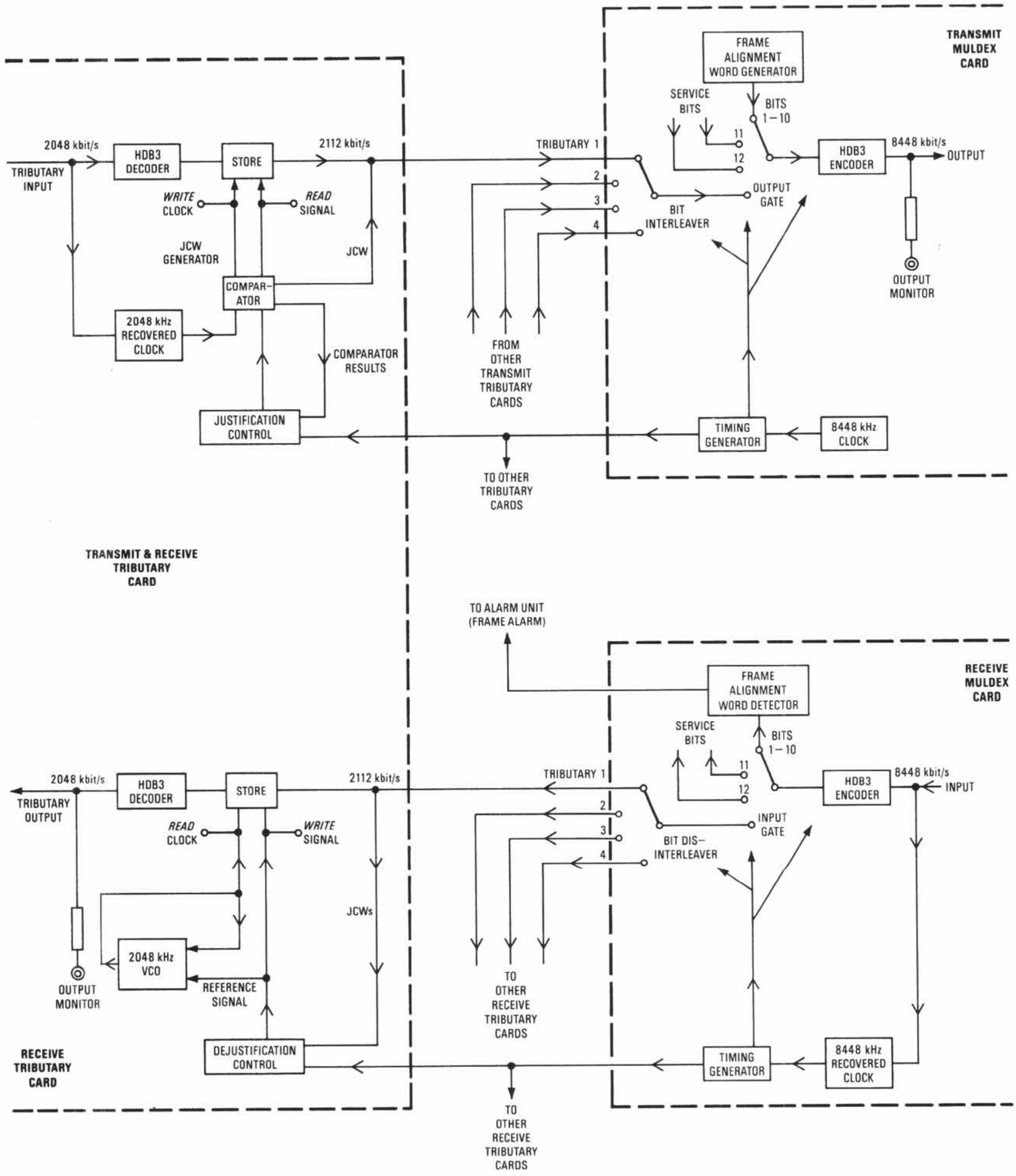


Fig. 6



JCW: Justification control word VCO: Voltage-controlled oscillator

Fig. 8—Simplified block schematic of 2–8 Mbit/s digital multiplex

Frame Alignment

The frame starts with the 10 bit FAW, which is generated within the muldex and inserted into the first 10 digit time-slots. At the distant demultiplex, the FAW is monitored, and the function of all other digits can be determined by their displacement from the FAW.

Distant Alarms

Bits 11 and 12 are used to transmit alarm conditions in the backward direction over the system. They are normally set to logic 0, but change to logic 1 when the alarm condition occurs.

Bit 11—Transmission of distant alarms
Bit 12—Transmission of distant errors

Justification

Justification is necessary to successfully interleave inputs which, although nominally at the same rate, actually vary by a specified tolerance. These inputs are described as being *plesiochronous*. In Fig. 7, the input bit rates are with respect to the nominal bit rates of 2048 kbit/s.

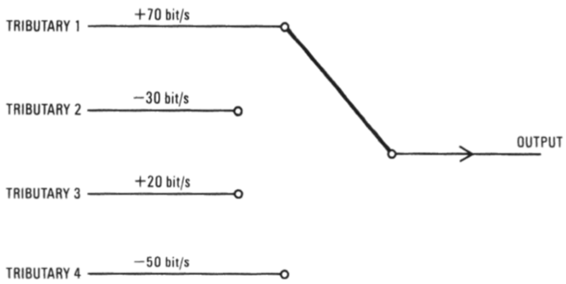


Fig. 7

Each of the inputs is at a different speed and so needs to be switched through to the output a different number of times per second. As these input bit rates are determined by the 30-channel PCM muldexes, they cannot be changed by the 2–8 Mbit/s muldex; in fact, the 2–8 Mbit/s muldex effectively synchronises itself to the four inputs.

In each frame, the 2–8 Mbit/s muldex generates one extra time-slot per tributary, called the *justifiable digit time-slot* (JDT). These time-slots are in set 4 (see Fig. 6) and are allocated as follows:

Set 4 bit 5—tributary 1
Set 4 bit 6—tributary 2
Set 4 bit 7—tributary 3
Set 4 bit 8—tributary 4

Although the JDTs are generated in each frame, they are not always used to transmit data from the appropriate tributary. This depends on the input speed of the tributaries. If the input bit rate is exactly 2048 kbit/s, the JDT is used 50% of possible occasions; that is, in every other frame on average. If the input bit rate is above 2048 kbit/s, the JDT is used more than once every other frame. If the input speed is below nominal, the JDT is used less than once every other frame.

The receive muldex must know whether the JDT contains a valid tributary bit, or just a digit which has been inserted by the transmit muldex at the far end. To interpret the JDTs accurately, control words known as *justification control words* (JCWs) are transmitted between the muldexes. The JCWs are 3 bit words, which are distributed over sets 2–4. Their allocation is as follows.

JCW for tributary 1—bit 1 of sets 2, 3 and 4
JCW for tributary 2—bit 2 of sets 2, 3 and 4
JCW for tributary 3—bit 3 of sets 2, 3 and 4
JCW for tributary 4—bit 4 of sets 2, 3 and 4

The meanings attributed to the JCW are as follows:

000—JDT carries a valid tributary bit
111—JDT does not carry a valid tributary bit

Frames not carrying a valid tributary bit are referred to as being *justified*.

Three bits distributed over sets 2, 3 and 4 are used to give the JCWs some degree of immunity to errors. If one of the three bits is corrupted during transmission, the significance of the JCW does not change because the receive muldex acts on the majority of the three bits. It is very important that the justification process is performed accurately because any mis-operation results in a 2 Mbit/s output signal having one more, or one less, bit than it should have. This causes the connected 30-channel PCM muldex to lose frame alignment.

The justification strategy used caters for changes of input speed of up to 9962 bit/s (±4981 bit/s), as this is the number of frames per second. The permissible variation of input speed is ±102 bit/s, which is well catered for.

OPERATION OF THE 2–8 Mbit/s MULDEX

Fig. 8 shows a block diagram of the 2–8 Mbit/s muldex. The following describes the operation of the muldex; the transmit direction is considered first.

Transmit Direction

HDB3 Decoder

The various integrated circuits used on the equipment use transistor-transistor logic (TTL), which recognises only two logic levels. Because the incoming HDB3 signal has three levels, it must be decoded into binary before being processed by the equipment. This can be done by a circuit using five or six integrated circuits (ICs).

2048 kHz Recovered Clock

The muldex requires a clock at the incoming bit rate to operate the ICs used in the equipment. This clock is extracted from the incoming signal by using a clock extraction circuit, similar to that shown in Fig. 9.

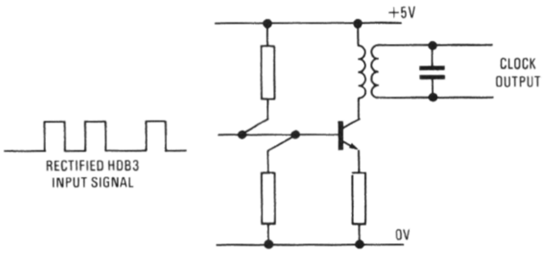


Fig. 9

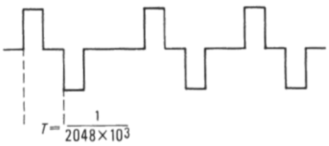
The input to the base of the transistor is a rectified version of the signal applied to the input of the equipment (HDB3 with 50% duty cycle). Although tuned to 2048 kHz, the tuned circuit resonates at the incoming bit rate because of a frequency component inherent within the input signal.

Fig. 10(*a*) shows an example of an HDB3 signal from which timing information could be extracted. The 50% duty cycle results in a MARK being at the positive or negative voltage for half a digit time-slot and zero voltage for the other half. After rectification, this signal will be as shown in Fig. 10(*b*).

Although the input signal is non-periodic and therefore has a continuous spectrum, inspection of the rectified version would indicate that a frequency component at $1/T$ hertz is present. The rectified waveform can be resolved into two components:

(*a*) a non-periodic component having a continuous spectrum, and

(*b*) a periodic component at the line bit rate. This component produces the clock.



(a)

(b)

Fig. 10

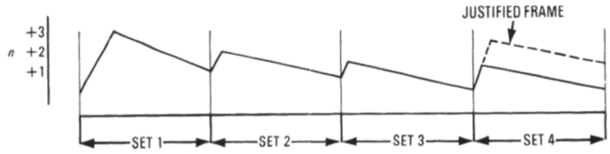


Fig. 12

At the beginning of set 4, either one or two *read* pulses are deleted, depending upon whether the frame is justified. The number of bits held in the store at various stages in the frame is shown in Fig. 12.

Phase Comparator

At the beginning of the frame, the decision whether to use the JDT is taken. This is done by the phase comparator, which monitors the relative phase difference between the *write* clock and the *read* signal. Because the *read* signal is at a basically higher frequency than the *write* clock, it tends to advance its phase relative to the *read* signal. When the *read* signal leads the *write* clock, one *read* signal pulse is deleted, thereby retarding the phase of the *read* signal.

The *read* signal pulse is removed during bits 5–8 of set 4. (The actual bit removed depends on which tributary is being considered.) In addition to controlling the JDT, the phase comparator also controls the generation of the JCW:

111 on justified frames
000 on unjustified frames

The JCWs are then inserted into their appropriate time-slot.

Justification

An elastic store is used to hold the decoded data leaving the HDB3 decoder. The incoming data is entered into the store by the *write* clock, and taken out of the store by the *read* signal. The *write* clock is at the line bit rate, whereas the *read* signal is derived from the muldex master oscillator and is at a nominal rate of 2112 kHz, although bits are removed at strategic points to make the average rate equal to the rate of the *write* clock. The 2112 kHz *read* signal is inhibited during the following periods:

(*a*) bits 1–12 of set 1 (three pulses removed),
(*b*) bits 1–4 of sets 2, 3 and 4 (1 pulse removed) on each set, and
(*c*) bits 5–8 on justified frames (1 pulse removed).

The form of the *write* clock and *read* signal are shown in Fig. 11. The *read* pulse in the JDT is inhibited on justified frames.

Over the short term (that is, one set), the two clocks have different frequencies, but over the long term (for example, several frames), the two clocks have the same frequency; that is, the incoming signal bit rate.

The number of bits held in the store varies over the frame. If, at the beginning of the frame, the number of bits held in the store is n, during the transmission of bits 1–12 of the frame, three more bits per tributary would have arrived, and so the number of bits in the store is now $n + 3$. Over the remainder of set 1, the number of bits in the store is reduced, because they are being entered at 2048 kHz and removed at 2112 kHz. A similar thing happens at the beginning of sets 2, 3, but here the number of bits held in the store increments by 1, because only one *read* pulse is deleted.

Interleaving

After the justification process has been successfully completed, the four tributary signals, now running at 2112 kbit/s, can be successfully multiplexed together.

Frame Alignment

Because the FAW can be imitated by traffic, the choice and length of the FAW are important. With a 10 bit word, and random data, there is a 1 in 2^{10}, (that is, 1 in 1024) possibility that any block of 10 digits could imitate the FAW. Therefore, the longer the FAW, the less is the chance that it could be imitated in a given period. Conversely, as the FAW does not convey tributary information, it should be kept as short as possible. When the receive muldex is attempting to gain frame alignment, any block of 10 bits conforming to the FAW is

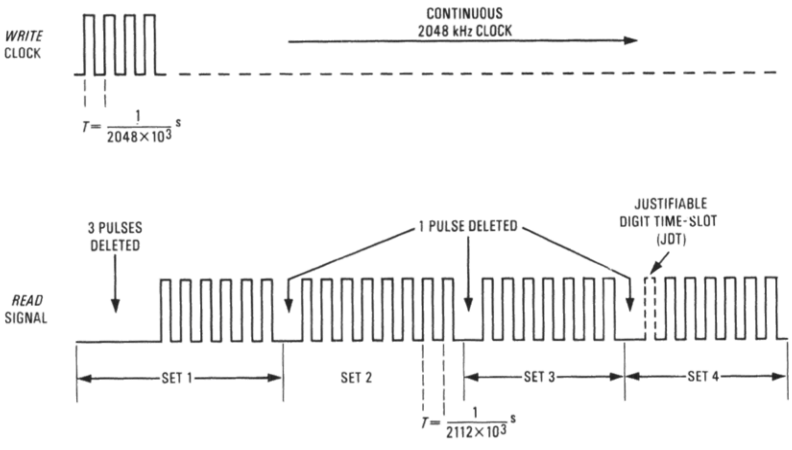


Fig. 11

provisionally accepted as the FAW, and is checked in subsequent frames. If the 10 bits accepted were the FAW, they would be confirmed in subsequent frames. If the 10 bits were an imitation, a different pattern would be present on the next frame and the muldex would then continue the search for the FAW in the incoming data.

The choice of FAW is important, because it should be impossible to imitate the FAW by examining some digits of the FAW and some of the adjacent digits. This is the case for the FAW used (see Fig. 13).

No combination of the digits XXX or YYY could cause patterns A or B to imitate the FAWs.

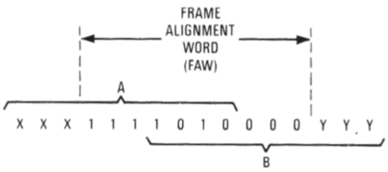


Fig. 13

Master Oscillator

The master oscillator (MO) is a self-contained crystal oscillator running at a nominal speed of 8448 kHz, with a frequency tolerance of 30 parts per million, which gives an actual frequency of 8448 kHz ±255 Hz. The output bit rate is at this frequency, and, because of this, the justification process must be performed in the 8–34 Mbit/s muldex to accommodate four plesiochronous 8 Mbit/s inputs.

The associated timing generator produces all the timing waveforms to drive the various ICs associated with the transmit direction of the muldex.

Receive Direction

In the receive direction, many of the processes performed are the inverse of those performed in the transmit direction and consequently are not considered here in detail. The following points are, however, important.

Recovered Clock

The receive muldex must operate at exactly the same rate as the transmit muldex at the distant end of the route. To achieve this, a clock is extracted from the incoming 8 Mbit/s signal and is then synchronised to the MO in the distant muldex. This effect results in the actual line bit rate in the two directions of transmission being slightly different, because each direction is controlled by a different MO.

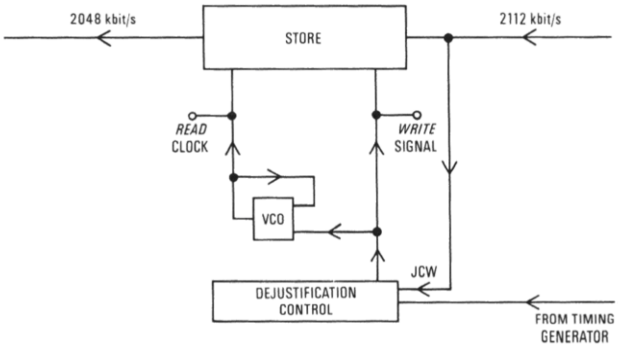
Frame Alignment Detector

When the muldex is first switched on, or after a short break in transmission, it is out of alignment, and searches for the FAW in the incoming data. Once it is in alignment, only frame bits 1–10 are monitored to ensure that the FAW is being correctly received. If four consecutive FAWs are not successfully detected, the muldex is then out of alignment and the search commences. The muldex can determine the significance of all bits in the frame by their displacement from the FAW.

Dejustification

Fig. 14 shows the various circuit elements concerned with the dejustification process.

The demultiplexed 2112 kbit/s signal is applied to the store and is entered into the store by the *write* signal. *Write* signal pulses occur during time-slots that contain valid tributary data, and are inhibited during other time-slots. Because of this, the *write* signal has the same form as the *read* signal at the distant end, which was shown in Fig. 11. The dejustification control



JCW: Justification control word
VCO: Voltage-controlled oscillator

Fig. 14

circuitry monitors the JCW, and this determines whether a *write* pulse is enabled during the JDT. If the JCW is 000, the *write* pulse is enabled; if the JCW is 111, the *write* pulse is inhibited during the JDT.

The 2048 kbit/s signal is read out of the store by the *read* clock, which is at exactly the same rate as the applied 2048 kbit/s signal at the distant end. The *read* clock is obtained from a voltage-controlled oscillator (VCO), which uses the *write* signal as its reference. Fig. 15 shows the various elements that make up the VCO.

The phase comparator monitors the relative phase of the two inputs and produces a digital signal with a variable MARK:SPACE ratio at point A. The low-pass filter then produces a DC signal that is proportional to the MARK:SPACE ratio, which is then used to vary the capacitance of the oscillator tuned circuit, thereby changing the frequency of the *write* signal.

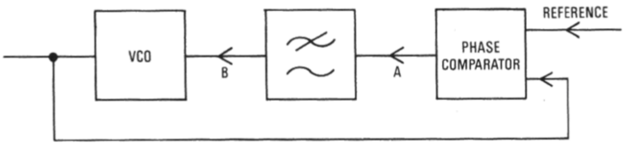


Fig. 15

OTHER MULDEXES

Although not described here in detail, the 8–34, 34–140 and 8–120 muldexes operate on the same principles as the 2–8 Mbit/s muldex. Each of these muldexes has a frame structure similar to the 2–8 Mbit/s muldex so that interleaving, justification and frame alignment can be carried out. The interface code used at 68 and 140 Mbit/s is coded mark inversion (CMI). This is a two-level non-return-to-zero code in which binary 0s are represented by a low level followed by a high level, each for a half-digit time-slot. Binary 1s are encoded as alternate high and low levels for the entire digit time-slot. An example of CMI coding is shown in Fig. 16.

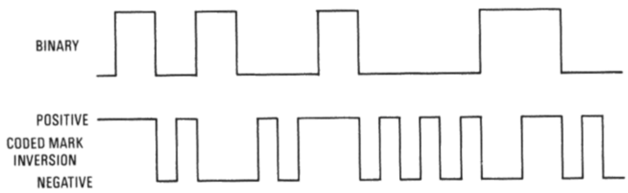


Fig. 16

The advantages of CMI are that:

(*a*) it is easy to implement in terms of hardware,
(*b*) it contains a high level of timing component, and
(*c*) it makes equaliser design easy as it is a balanced code.

TABLE 2

Alarm	Condition	AIS Signal Transmitted	Distant Alarm Transmitted	Category
Power	Failure of main or derived supplies	*	*	Prompt
Muldex Input Fail	Loss of 8 Mbit/s input	Yes	Yes	Prompt
Loss of Alignment	Loss of four consecutive FAWs	Yes	Yes	Prompt
Receive AIS	All logic 1s received at 8 Mbit/s input	Yes	Yes	In-station
Distant	Bit 11 received at logic 1	No	No	In-station
Tributary Input Fail	Loss of 2 Mbit/s input	Yes	No	Prompt

* Depends on which supply has failed

ALARMS AND MONITORING

In the event of a fault, the muldex equipment can extend one of three alarm conditions to the station alarm system:

(*a*) PROMPT, requiring immediate attention;
(*b*) DEFERRED, not requiring immediate attention; and
(*c*) IN-STATION, for information only.

The alarm strategy is such that, whenever possible, one fault causes only one prompt alarm. Alarms raised at other points in the network are in-station. This is done by the use of a special signal known as the *alarm indication signal* (AIS), which is a signal of all logic 1s. The digital muldex equipment monitors the inputs and, when a major fault occurs, a prompt alarm is given on the first equipment detecting the failure, and the AIS signal is sent forward in place of the faulty signal. The AIS signal causes an in-station alarm to be raised at subsequent points along the route. Additionally, a major fault in the high bit rate input to a muldex causes a distant alarm to be transmitted to the distant muldex in the opposite direction to the original fault. This is done by setting one of the service digits to logic 1. (Bit 11 in the case of the 2–8 Mbit/s muldex.) The alarms given in Table 2 are with respect to a 2–8 Mbit/s muldex, although all muldexes have the same alarm conditions.

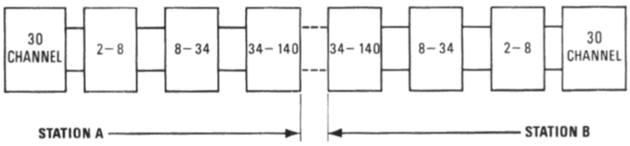
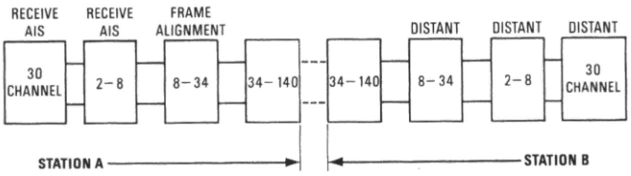


Fig. 17

Consider, in the example shown in Fig. 17, that the FAW generator has failed in the 8–34 Mbit/s muldex in station B. The signal is processed by the 34–140 Mbit/s muldexes in stations A and B, but, when it is demultiplexed to 34 Mbit/s, it causes a frame alignment alarm on the 8–34 Mbit/s muldex in station A.

The 8–34 Mbit/s muldex in station A extends the AIS on its four receive tributaries and transmits a distant alarm to the 8–34 Mbit/s muldex in station B.

The four 2–8 Mbit/s muldexes in station A show a receiving AIS alarm, then extend this to the connected 30-channel PCM muldexes and transmit a distant alarm to the four 2–8 Mbit/s muldexes in station B.



AIS: Alarm indication signal

Fig. 18

The alarm displayed for this fault is as shown in Fig. 18.

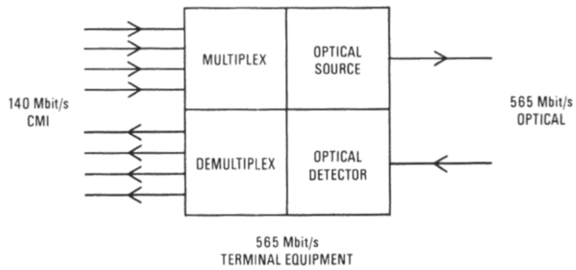
Monitoring

All digital muldexes have protected test points on each of the tributary inputs and the muldex output. There is a range of testers that can be connected to these test points to determine whether the signal is faulty at the equipment interfaces:

Tester 246—2 Mbit/s alignment tester
Tester 281—8 and 34 Mbit/s alignment tester
Tester 282—68 and 140 Mbit/s alignment tester
ARG 1038—120 Mbit/s alignment tester

FUTURE DEVELOPMENTS

Although 140 Mbit/s is the highest bit rate system in production, there are 565 Mbit/s prototype evaluation routes operating over single-mode optical fibres. The terminal equipment for this system (see Fig. 19) consists of a combined muldex and optical line terminating equipment. Four 140 Mbit/s signals are applied to the equipment, where they are digitally multiplexed by using the principles previously described; then, after being suitably encoded, they are used to switch an optical source on and off.



CMI: Coded mark inversion

Fig. 19

A22 The purpose of a project programme is to show clearly the labour, financial and planning resources required; to assess the long-term labour requirements of the project; to enable the effects of financial and other restrictions to be assessed. The programme also assists in governing the planning output for production at the right time to meet business targets and policies.

Q23 Why is it necessary to identify the material requirements in an estimate? *(1 min)*

A23 To ensure that the materials are ordered and obtained just before their requirement date.

Q24 What financial considerations must be given to a project before the go-ahead for the project is authorised? *(2 min)*

A24 Points to consider would be:

(*a*) Is the expense justifiable in terms of the benefits arising from the project?
(*b*) Is there sufficient capital available?
(*c*) Would it be cheaper to use outside contractors?
(*d*) How much would need to be charged for the services arising from the project?

Q25 Complete the following from the associated list.

(*a*) *Work that requires .... will require supervision.*

(*i*) *manpower*
(*ii*) *materials*
(*iii*) *co-ordination*
(*iv*) *expertise*

(*b*) *All work reports should be submitted ....*

(*i*) *daily*
(*ii*) *promptly*
(*iii*) *at irregular intervals*
(*iv*) *on completion of a task* *(1 min)*

A25 (*a*) (*iii*) co-ordination.
(*b*) (*ii*) promptly.

Q26 Five men erect three poles in 1 h 45 min. Calculate the productivity of the team. *(2 min)*

A26

$$\text{Productivity} = \frac{\text{end products}}{\text{manhours}},$$

$$= \frac{3 \text{ poles}}{1{\cdot}75 \times 5 \text{ manhours}},$$

$$= \underline{0{\cdot}34 \text{ poles/manhour}}.$$

Q27 What is the basic difference between bar charts and critical-path-analysis (CPA) charts? *(2 min)*

A27 Bar charts allow for a sequential flow of events, no two events occurring simultaneously. CPA charts allow for a sequential flow of events but also allow for simultaneous events occurring. Thus the CPA method allows for more flexibility and better project co-ordination.

Q28 How may project performance be measured? *(2 min)*

A28 Project performance may be measured by comparing actual activity completion times with estimated activity completion times. It may also be measured by comparing actual effort used in activity completion with standard effort derived from work-study techniques.

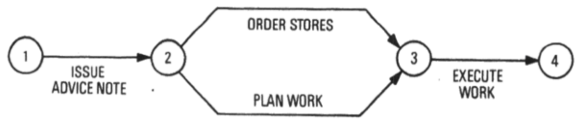
Q29 A project consists of the following activities:

(*a*) *issue advice note,*
(*b*) *order stores,*
(*c*) *plan work, and*
(*d*) *execute work.*

Would a bar chart or a critical-path-analysis (CPA) chart be used to control this project?
Give reasons for your selections of chart and draw the chart. *(3 min)*

A29 A CPA chart would be used to control this project because two of the activities may be carried out simultaneously; these are activities (*b*) and (*c*). Neither of these two activities will be dependent on the completion of the other and thus they may be carried out in parallel.

The chart is shown in the sketch.



Q30 Give three examples of prevention maintenance. *(1 min)*

A30 (*a*) Replacement of equipment before faults occur.
(*b*) Pressurising cables.
(*c*) Filling cables with jelly.

For examples (*b*) and (*c*), if the repair to a faulty cable sheath is made before an electrical fault occurs, the repair comes under the category of preventive maintenance.

Q31 What is the main cause of cable faults? *(1 min)*

A31 The ingress of moisture, or the cable being cut.

Q32 In terms of the customer, what is the fault condition when a full short circuit occurs on the line? *(1 min)*

A32 The customer whose line is short circuited will receive no dial tone or will not be able to break dial tone. A customer calling the faulty line will receive permanent engaged tone signal.

Q33 What is a typical maximum permissible loop resistance of a telephone line connection to the public telephone network? *($\frac{1}{2}$ min)*

A33 1000 Ω.

Q34 Which two line parameters are checked when a DC test is used on a line? *($\frac{1}{2}$ min)*

A34 Loop resistance and insulation resistance.

Q35 The measured insulation resistance of a 3·4 km line is given as 2000 MΩ.
Determine the insulation resistance per kilometre. *(2 min)*

A35 The insulation resistance of 3·4 km = 2000 MΩ.

Thus, the insulation resistance of 1 km of line = 2000 × 3·4,

= 6800 MΩ.

[*Tutorial Note:* A standard value of insulation resistance is set for each type of cable, using a 1 km length of that cable.]

Q36 A 36 km length of line has a measured loop resistance of 2140 Ω. During a Varley test for an earth fault, the variable resistor of the Varley circuit was found to measure 560 Ω using equal ratio arms. What is the estimated distance from the testing end to the fault assuming that the faulty and good wires used in the test have equal resistance values? *(3 min)*

A36

$$\text{Distance to the fault} = \left(1 - \frac{\text{Varley reading}}{\text{loop resistance}}\right) \times L \text{ km}.$$

Substituting the given values,

$$\text{distance to the fault} = \left(1 - \frac{560}{2140}\right) \times 36,$$

$$= (1 - 0{\cdot}261) \times 36,$$

$$= 0{\cdot}739 \times 36,$$

$$= \underline{26{\cdot}6 \text{ km}}.$$

Q37 In terms of locating the distance to a fault, distinguish between the Varley test and the Murray test. (3 *min*)

A37 The Varley test enables the tester to localise the fault between two manholes or two footway boxes. If the fault is of such a nature that the cable section between the two points needs to be replaced, then this method is adequate. If, however, the fault is of such a nature that a repair is required at the actual point of the cable fault, then the Murray test is used as, for short distances, this test gives very accurate distance readings.

Q38 In the Varley test, the bridge circuit is balanced by using ratio arms and a variable resistor. How is balancing achieved in the Murray test? (2 *min*)

A38 The Murray test uses a potentiometer to balance the bridge circuit. The test should be used only where the resistances being measured are considerably less than the resistance of the slide wire of the potentiometer being used.

Q39 What are the advantages of pressurising cables? (3 *min*)

A39 (*a*) A higher standard of insulation resistance is provided.
(*b*) The internal pressure in the cable provides protection for the cable core against the ingress of water or damp air.
(*c*) Pressure sensors along the cable route provide a means of locating cable sheath faults before an electrical fault develops.
(*d*) The reduction of cable breakdowns improves the service, and thus help to create a good public image for the telephone company.

Q40 State the two types of cable-pressurising systems used in the national telephone network and state where each of these systems are used in the network. (2 *min*)

A40 The two systems are:

(*a*) the static system, and
(*b*) the continuous-flow system.

The static system is used in trunk and junction cables and the continuous-flow system is used in local cables between the exchange and the primary cross-connection point cabinet.

Q41 Explain the term 'rodding' and list three typical methods of rodding. (3 *min*)

A41 Before a cable can be pulled into a duct, a draw rope must be provided throughout the length of the duct. If a draw rope has not been provided during the laying of the duct, the duct must be rodded so that a draw rope may be pulled in.
Three typical methods of rodding are:

(*a*) by hand, using coupled rods,
(*b*) by using a duct motor, and
(*c*) by using a machine with a continuous PVC rod; The machine may be mounted on a vehicle.

[*Tutorial Note:* The name *rodding* derives from the days when the only method available was method (*a*) above.]

Questions and answers contributed by N. C. Webber

CITY AND GUILDS OF LONDON INSTITUTE

Telecommunications Technicians (New) Scheme

The following questions are from examination papers set for the City and Guilds of London Institute's (CGLI's) new 271 Telecommunications Technicians Scheme, and are reproduced with the permission of the CGLI. The answers given have been prepared by independent authors. Answers to some questions are omitted because of insufficient space. Students studying BTEC courses at the higher level may find that these questions are useful for revision.

CGLI: CIRCUIT THEORY T4 (1985)

Students were required to answer six questions. The total time allowed was three hours. Students are advised to read the notes above

[*Tutorial Note:* All solutions are worked to three significant figures.]

Q1 (*a*) *A coil may be represented as an inductance of 200 μH in series with a resistance of 15 Ω.*
For a frequency of 25 kHz, determine the impedance of the coil in

(*i*) *cartesian form*
(*ii*) *polar form.*

(*b*) *For the coil in* (*a*) *at 25 kHz calculate*

(*i*) *the admittance*
(*ii*) *the values of parallel inductance and resistance which can represent the coil at this frequency.*

A1 (*a*) (*i*) The impedance of the coil, Z, in cartesian form, is given by

$$Z = R + j\omega L,$$

where R is the resistance, ω is $2\pi \times$ frequency, and L is the inductance.
In this case,

$$Z = 15 + j2\pi \times 25 \times 10^3 \times 200 \times 10^{-6},$$
$$= \underline{15 + j31{\cdot}4\,\Omega}.$$

(*ii*) In polar form,

$$Z = \sqrt{(15^2 + 31{\cdot}4^2)}\ \angle \tan^{-1}\left(\frac{31{\cdot}4}{15}\right),$$
$$= \underline{34{\cdot}8\ \angle 64{\cdot}5^\circ\,\Omega}.$$

(*b*) (*i*) The admittance, Y

$$= \frac{1}{Z} = \frac{1}{34{\cdot}8\ \angle 64{\cdot}5^\circ} = \underline{0{\cdot}0287\ \angle -64{\cdot}5^\circ\ \mathrm{S}}.$$

[*Tutorial Note*]: The admittance could have been calculated from the cartesian form of Z and rationalised; this is a more tedious process.]

(*ii*) By representing the admittance in the cartesian form, the parallel components are given.

Thus,
$$Y = 0{\cdot}0287\ \angle -64{\cdot}5^\circ,$$
$$= 0{\cdot}0287 \cos 64{\cdot}5^\circ - j0{\cdot}0287 \sin 64{\cdot}5^\circ,$$
$$= 0{\cdot}0124 - j0{\cdot}0259,$$
$$= G + jB,$$

where G and B are the parallel components.
Therefore, the parallel resistance

$$= \frac{1}{G} = \frac{1}{0{\cdot}0124} = \underline{80{\cdot}6\,\Omega}.$$

The parallel reactance

$$= -\frac{1}{B} = \frac{1}{0{\cdot}0259} = 38{\cdot}6 = \omega L_p,$$

where L_p is the parallel inductance.

Hence,

$$L_p = \frac{38 \cdot 6}{2\pi \times 25 \times 10^3} = \underline{246\,\mu\text{H}}.$$

Q2 For the circuit shown in Fig. 1, at a frequency of 2 kHz,
(a) calculate the current taken from the supply,
(b) determine the parallel inductance required to produce resonance, and
(c) calculate the Q-factor of the resonant circuit.

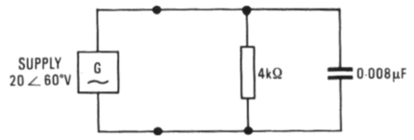


Fig. 1

A2 (*a*) In this case, since the resistor (R) and capacitor (C) are in parallel, the best relation to apply is:

$$\text{current, } I = VY,$$

where $V = 20\angle 60^\circ$ and $Y = \dfrac{1}{R_p} + j\omega C$.

Substituting values gives:

$$Y = \frac{1}{4000} + j2\pi \times 2 \times 10^3 \times 0 \cdot 008 \times 10^{-6},$$

$$= (250 + j101) \times 10^{-6}\,\text{S},$$

$$= 270 \times 10^{-6}\angle 22^\circ\,\text{S}.$$

Hence, $$I = 20\angle 60^\circ \times 270 \times 10^{-6}\angle 22^\circ,$$

$$= \underline{5 \cdot 39\angle 82^\circ\,\text{mA}}.$$

(*b*) For resonance, a parallel inductor of inductance $L = 1/\omega C$ is used.

$$\therefore \quad L = \frac{1}{(2\pi \times 2 \times 10^3)^2 \times 0 \cdot 008 \times 10^{-6}},$$

$$= \underline{0 \cdot 791\,\text{H}}.$$

(*c*) The Q-factor for a parallel resonant circuit

$$= \frac{\text{susceptance of } L \text{ or } C \text{ at resonance}}{\text{parallel conductance}},$$

$$= \frac{101 \times 10^{-6}}{250 \times 10^{-6}} = \underline{0 \cdot 404}.$$

Q3 Using Thévenin's theorem, determine the magnitude of the current in the 12 Ω resistor in the network shown in Fig. 2.

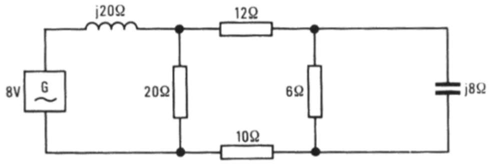
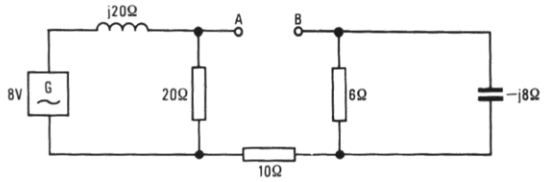


Fig. 2

A3 To determine the current in the 12 Ω resistor by using Thévenin's theorem, the 12 Ω resistor is first removed and the Thévenin equivalent circuit for the terminals of the remaining circuit is determined. These terminals are denoted A and B in the sketch.

The voltage of the Thévenin equivalent source (V_T) is the open-circuit voltage across AB, and this is the voltage across the 20 Ω resistor since no current flows in the right-hand part of the circuit.



Thus,

$$V_T = 8 \times \frac{20}{20 + j20} = \frac{8}{1 + j} = 5 \cdot 66\angle -45^\circ\,\text{V}.$$

The impedance of the Thévenin source is the impedance 'seen' at AB with the 8 V source removed and replaced by a short circuit.

Hence,

$$Z_T = \frac{20 \times j20}{20 + j20} + 10 + \frac{6(-j8)}{6 - j8},$$

$$= \frac{j20}{1 + j} + 10 + \frac{(-j24)}{3 - j4},$$

$$= \frac{j20(1 - j)}{2} + 10 - \frac{j24(3 + j4)}{25},$$

$$= j10 + 10 + 10 - \frac{j72}{25} + \frac{96}{25},$$

$$= \underline{23 \cdot 84 + j7 \cdot 12\,\Omega}.$$

Returning the 12 Ω resistor to terminals AB, the current in the 12 Ω resistor is given by

$$\frac{V_T}{Z_T + 12} = \frac{5 \cdot 66\angle -45^\circ}{35 \cdot 84 + j7 \cdot 12}.$$

The magnitude of the current

$$= \frac{5 \cdot 66}{\sqrt{(35 \cdot 84^2 + 7 \cdot 12^2)}} = \frac{5 \cdot 66}{36 \cdot 5} = \underline{0 \cdot 155\,\text{A}}.$$

Q4 (a) State the superposition principle.
(b) Use the superposition principle to calculate the currents in the circuit shown in Fig. 3.

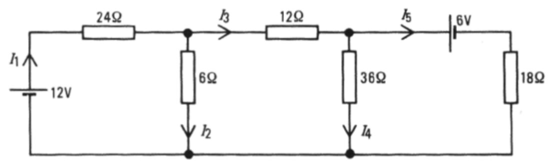


Fig. 3

A4 (*a*) In any network containing two or more sources, the current in any branch is the algebraic sum of the currents produced in that branch by each source taken alone with the other sources replaced by their internal impedances.

(*b*) First consider the 6 V source replaced by a short circuit, and calculate the currents due to the 12 V source. Let these currents be designated i_1, i_2, i_3 etc. corresponding to I_1, I_2, I_3 etc.

Let R_{in} be the total resistance seen by the source; this is calculated as follows:

The total resistance of 18 Ω in parallel with 36 Ω

$$= \frac{18 \times 36}{18 + 36} = 12\,\Omega.$$

The total resistance of 6 Ω in parallel with two 12 Ω resistances in series

$$= \frac{6 \times 24}{6 + 24} = 4 \cdot 8\,\Omega.$$

$$\therefore \quad R_{in} = 24 + 4 \cdot 8 = 28 \cdot 8\,\Omega.$$

Hence, $$i_1 = \frac{12}{28{\cdot}8} = 0{\cdot}417\,\text{A}.$$

By the current division rule,

$$i_2 = \frac{24}{24+6}\,i_1 = 0{\cdot}333\,\text{A} \qquad \text{and,}$$

$$i_3 = \frac{6}{30}\,i_1 = 0{\cdot}083\,\text{A}.$$

Similarly $$i_4 = \frac{18}{54}\,i_3 = 0{\cdot}028\,\text{A}, \qquad \text{and}$$

$$i_5 = \frac{36}{54}\,i_3 = 0{\cdot}055\,\text{A}.$$

By a similar procedure, expressing the current as i_1', i_2' etc., the effect of the 6 V source alone is calculated.

[*Tutorial Note:* The currents along the top of the circuit are reversed.]

Resistance seen by the 6 V source = 29·5 Ω.
Therefore,

$$i_5' = -\frac{6}{29{\cdot}5} = -0{\cdot}203\,\text{A},$$

$$i_4' = 0{\cdot}203 + \frac{16{\cdot}8}{52{\cdot}8} = 0{\cdot}065\,\text{A},$$

$$i_3' = -0{\cdot}203 \times \frac{36}{52{\cdot}8} = -0{\cdot}138\,\text{A},$$

$$i_2' = 0{\cdot}138 \times \frac{24}{30} = 0{\cdot}110\,\text{A}, \qquad \text{and}$$

$$i_1' = -0{\cdot}028\,\text{A}.$$

Thus,

$I_1 = 0{\cdot}417 - 0{\cdot}028 = \underline{0{\cdot}389\,\text{A}}$, $I_2 = 0{\cdot}333 + 0{\cdot}110 = \underline{0{\cdot}443\,\text{A}}$,

$I_3 = 0{\cdot}083 - 0{\cdot}138 = \underline{-0{\cdot}055\,\text{A}}$, $I_4 = 0{\cdot}028 + 0{\cdot}065 = \underline{0{\cdot}093\,\text{A}}$, and

$I_5 = 0{\cdot}055 - 0{\cdot}203 = \underline{-0{\cdot}148\,\text{A}}$

Q5 *(a) State the maximum power transfer theorem for a complex impedance load connected to a complex impedance source.*

(b) An amplifier with a resistive output impedance of 25 Ω has to supply maximum power to an 8 Ω resistance.

Calculate the turns ratio of a transformer which will provide the maximum power transfer condition and, on a diagram, show the connections.

(c) At a particular frequency, the output impedance of the amplifier in (b) becomes (25 − j10). Give TWO *ways for the matching circuit to be modified to maintain maximum power transfer at this frequency.*

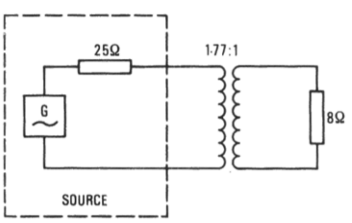
A5 (*a*) For maximum power transfer from a source to a load, the load impedance must be the complex conjugate of the source impedance.

(*b*) If the primary-to-secondary turns ratio is n, then

$$25 = n^2 \times 8.$$

$$\therefore \quad n = \sqrt{\left(\frac{25}{8}\right)} = 1{\cdot}77.$$

The circuit is as shown in the sketch.



(*c*) When the source impedance changes to 25 − j10 Ω, the effective load must become 25 + j10 Ω.

This can be obtained in two ways:

(*i*) +j10 Ω added in series with the primary, and
(*ii*) $+\text{j}10/n^2 = +\text{j}3{\cdot}2\,\Omega$ added in series with the secondary.

Other alternatives using parallel inductors are possible, but a change in the turns ratio is required as well.

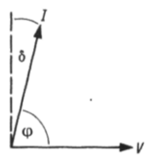
Q6 *(a) With the aid of a suitable phasor diagram, explain what is meant by the loss-angle of a capacitor.*

(b) With the aid of suitable phasor diagrams, show how a lossy capacitor may be represented as

(i) an admittance
(ii) an impedance.

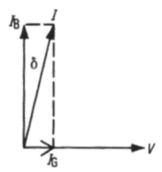
(c) A capacitor may be represented at 2 MHz by a capacitance of 10 pF in series with a resistance of 0·4 Ω. Determine the power factor of the capacitor.

A6 (*a*) See sketch (*a*). The loss angle $\delta = \pi/2 - \phi$ and is the angle by which the current fails to lead the voltage by $\pi/2$ rad. The power factor $\cos\phi = \sin\delta$. Since for a capacitor δ is small, $\sin\delta \approx \delta$; so δ = power factor.

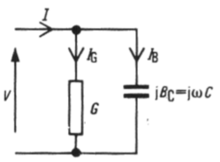


(*a*)

(*b*) (*i*) If the current is resolved in phase and in quadrature with V, these are the conductive and susceptive currents respectively shown in sketches (*b*) and (*c*).



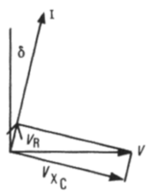
(*b*)



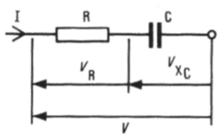
(*c*)

Then $Y = G + \text{j}B_C$.

Resolving the voltage in phase and quadrature with the current gives resistive and reactive components shown in sketches (*d*) and (*e*).



(*d*)



(*e*)

Then, $Z = R - \text{j}X_C$.

(*c*) If ω is $2\pi \times$ frequency, then

$$\delta = \omega CR = 2\pi \times 2 \times 10^6 \times 100 \times 10^{-12} \times 0{\cdot}4,$$
$$= \underline{5{\cdot}02 \times 10^{-4}}.$$

Q7 *(a) A loss-free line has a characteristic impedance of 75 Ω and a capacitance of 60 pF/m.*

Determine

(i) the inductance/unit length
(ii) the velocity of propagation.

(b) For the line in (a) at 25 MHz, calculate

(i) the phase-change coefficient
(ii) the line length for a phase change of 2π radians.

(c) At what frequency will the line length in (b) provide a phase change of 7π radians.

A7 (*a*) (*i*)

$$Z_0 = \sqrt{\left(\frac{L}{C}\right)}.$$

$$\therefore \quad 75 = \sqrt{\left(\frac{L}{60 \times 10^{-12}}\right)}.$$

$$L = 75^2 \times 60 \times 10^{-12},$$

$$= \underline{0{\cdot}3375\,\mu\text{H/m}}.$$

(*ii*) The velocity of propagation, V_p

$$= \frac{1}{\sqrt{(LC)}} = \frac{1}{\sqrt{(0{\cdot}3375 \times 10^{-6} \times 60 \times 10^{-12})}},$$

$$= \underline{2{\cdot}22 \times 10^8\ \text{m/s}}.$$

(*b*) (*i*) The phase-change coefficient $b = \omega\sqrt{(LC)}$.

$$\therefore \quad b = \frac{\omega}{V_p} = \frac{2\pi \times 25 \times 10^6}{222 \times 10^8} = \underline{0{\cdot}707\ \text{rad/m}}.$$

(*ii*) If l is the line length for a phase-change of 2π radians, then

$$bl = 2\pi.$$

$$l = \frac{2\pi}{0{\cdot}707} = \underline{8{\cdot}89\ \text{m}}.$$

(*c*) For $bl = 7\pi$ when $l = 8{\cdot}89$ m,

$$b = \frac{7\pi}{8{\cdot}89} = 2{\cdot}47\ \text{rad/m}.$$

Thus, the new ω

$$= 2{\cdot}47 \times 2{\cdot}22 \times 10^8 = 5{\cdot}49 \times 10^8.$$

The new frequency

$$= \frac{5{\cdot}49 \times 10^8}{2\pi} = \underline{87{\cdot}5\ \text{MHz}}.$$

Q8 (*a*) *Explain how the combination of an incident and a reflected voltage wave on an incorrectly terminated loss-free transmission line produces a standing wave.*

(*b*) *State the condition that applies when a standing wave is at*

(*i*) *a maximum*
(*ii*) *a minimum.*

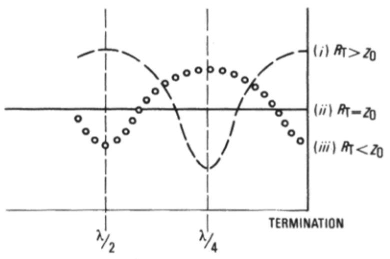
(*c*) *For resistance line terminations only, sketch and explain typical standing waves from the termination when it is*

(*i*) *equal to* Z_0
(*ii*) *greater than* Z_0
(*iii*) *less than* Z_0.

A8 (*a*) Viewed from a termination, the incident wave, of constant amplitude, progressively leads in phase with distance from the termination. The reflected wave, normally but not always of another constant amplitude, progressively lags in phase with distance from the termination. The voltage at any point on the line is the phasor sum of the incident and reflected voltages at that point. The phasor sum of the two constant quantities varies as the phase angle changes between them; therefore, the line voltage varies with distance, producing a standing wave.

(*b*) (*i*) At a maximum, the incident and reflected voltages are in phase.
(*ii*) At a minimum, they are in antiphase.

(*c*)



Q9 (*a*) *A resistive T-section attenuator has a characteristic impedance of 50 Ω and an attenuation coefficient of 12 dB. Calculate its component values.*

(*b*) *An asymmetric attenuator is shown in Fig. 4. Calculate its insertion loss when it is inserted between a source of resistance 100 Ω connected to AB and a load of 40 Ω connected to CD.*

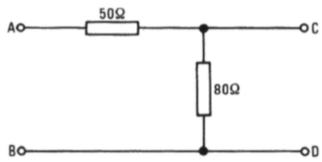
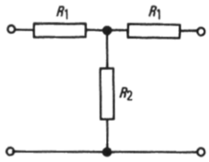


Fig. 4.

A9 The resistive T-section attenuator is shown in sketch (*a*).



(*a*)

The ratio of input voltage to output voltage, N, for the network when it is correctly terminated is related to the attenuation coefficient in decibels by

$$20\log_{10} N = 12\,\text{dB}.$$

$$\therefore \quad N = 4.$$

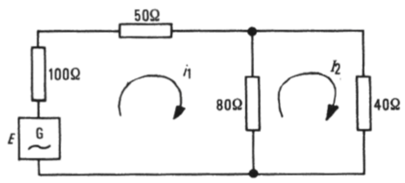
If R_0 is the characteristic resistance of the network, then

$$R_1 = R_0\frac{(N-1)}{(N+1)} = 50 \times \frac{3}{5} = \underline{30\,\Omega}.$$

$$R_2 = R_0\frac{2N}{N^2-1} = 50 \times \frac{8}{15} = \underline{26{\cdot}7\,\Omega}.$$

(*b*) The insertion loss is $20\log_{10}(I_1/I_2)$, where I_1 is the load current without insertion of the network, and I_2 is the load current with the network inserted. If E is the source EMF, then $I_1 = E/140$.

Sketch (*b*) shows the network inserted.



(*b*)

$$E = 230i_1 - 80I_2.$$

Also,
$$80i_1 = 120I_2.$$

$$\therefore \quad i_1 = 1{\cdot}5I_2.$$

$$\therefore \quad E = 230 \times 1{\cdot}5I_2 - 80I_2.$$

$$= 265I_2.$$

$$\therefore \quad I_2 = \frac{E}{265}.$$

The insertion loss

$$= 20\log_{10}\frac{E}{140} \times \frac{265}{E} = \underline{5{\cdot}54\,\text{dB}}.$$

Q10 (*a*) *Define the 'h' parameters of a two-port network.*

(*b*) *A bipolar junction transistor has the hybrid parameters*

$$h_{ie} = 1500\Omega,\ h_{re} = 10^{-4},\ h_{fe} = 120 \text{ and } h_{oe} = 2{\cdot}5 \times 10^{-5}\,\text{S}.$$

The transistor is used in an amplifier with a 2 kΩ collector load resistor.

The signal source has an EMF of 1·2 mV and an internal resistance of 500 Ω.
Calculate the output signal voltage across the collector load

(i) assuming the h_{re} and h_{oe} are negligible
(ii) taking h_{re} and h_{oe} as given.

A10 (*a*) [*Tutorial Note:* Standard definitions are required.]
(*b*) The equations for the hybrid equivalent circuit of the transistor are:

$$v_1 = h_{ie}\, i_b + h_{re}\, v_2, \text{ and}$$

$$i_c = h_{fe}\, i_b + h_{oe}\, v_2.$$

With a source e having resistance R_s,

$$v_1 = e - i_b R_s.$$

For a load R_L,

$$v_2 = -i_c R_L.$$

(*i*) With h_{re} and h_{oe} negligible,

$$v_1 = h_{ie}\, i_b, \quad \text{and} \quad i_c = h_{fe}\, i_b.$$

Thus,

$$e - i_b R_s = h_{ie}\, i_b.$$

$$\therefore \quad 1{\cdot}2 \times 10^{-3} = i_b(500 + 1500)$$

$$\therefore \quad i_b = \frac{1{\cdot}2 \times 10^{-3}}{2000}\,\mathrm{A} = 0{\cdot}6\,\mu\mathrm{A}.$$

Now,

$$i_c = 120 i_b = 120 \times 0{\cdot}6 \times 10^{-6} = 72\,\mu\mathrm{A}.$$

$$\therefore \quad v_2 = -72 \times 10^{-6} \times 2000 = \underline{-144\,\mathrm{mV}}.$$

(*b*) (*ii*) Taking h_{re} and h_{oe} as given,

$$1{\cdot}2 \times 10^{-3} - 500 i_b = 1500 i_b + 10^{-4} v_2.$$

$$\therefore \quad 1{\cdot}2 \times 10^{-3} = 2000 i_b + 10^{-4} v_2. \qquad \ldots (1)$$

$$i_c = 120 i_b + 2{\cdot}5 \times 10^{-5} v_2. \qquad \ldots (2)$$

$$\therefore \quad i_c = -\frac{v_2}{2000} = -5 \times 10^{-4} v_2. \qquad \ldots (3)$$

Substituting for i_c in equation (2) gives

$$-5 \times 10^{-4} v_2 = 120 i_b + 2{\cdot}5 \times 10^{-5} v_2.$$

$$\therefore \quad -52{\cdot}5 \times 10^{-5} v_2 = 120 i_b.$$

$$\therefore \quad i_b = \frac{-52{\cdot}5 \times 10^{-5}}{120} v_2,$$

$$= -4{\cdot}375 \times 10^{-6} v_2.$$

Substituting for i_b into equation (1) gives

$$1{\cdot}2 \times 10^{-3} = -2000 \times 4{\cdot}375 \times 10^{-6} v_2 + 10^{-4} v_2,$$

$$= (-8{\cdot}75 \times 10^{-3} + 10^{-4}) v_2,$$

$$= -8{\cdot}65 \times 10^{-3} v_2.$$

$$\therefore \quad v_2 = -\frac{1{\cdot}2 \times 10^{-3}}{8{\cdot}65 \times 10^{-3}} = -0{\cdot}139\,\mathrm{V},$$

$$= \underline{-139\,\mathrm{mV}}.$$

Answers contributed by L. J. Colenutt

CGLI: SWITCHING T5 OPTION (1985)

Students were required to answer five questions. The total time allowed was three hours. Students are advised to read the notes on p. 14

Q1 *Owing to a fault, a residential line receives calls intended for a commercial firm at the rate of 90 per hour. The family is away, so the calls are not answered.*
Determine

(a) the probability of the line being engaged if a caller listens to ringing-tone on an average for 30 s before clearing down; and
(b) the average number of callers receiving subscriber busy-tone simultaneously if, on average, a caller who finds the line engaged, clears down after 3 s,

A1 (*a*) If the calling rate is 90 calls per hour, and it is assumed that all the calls are due to the fault and are not genuinely intended for the residential line, and given that callers listen to ringing tone for 30 s on average,

the traffic in erlangs = the number of calls × average holding time,

$$= 90 \times \frac{30}{3600},$$

$$= 0{\cdot}75 \text{ erlangs}.$$

The probability of the line being engaged is numerically equal to the traffic carried in erlangs.

$$\therefore \quad \text{Probability} = \underline{0{\cdot}75}.$$

(*b*) The number of callers receiving busy tone per hour

$$= 0{\cdot}75 \times 90.$$

If the call holding time for calls meeting busy tone is 3 s, the traffic meeting busy tone

$$= 0{\cdot}75 \times 90 \times \frac{3}{3600},$$

$$= 0{\cdot}05625 \text{ erlangs}.$$

Now, the average number of callers receiving busy tone simultaneously is numerically equal to the traffic connected to busy tone; that is, $\underline{0{\cdot}05625}$.

Q2 *A new rural telephone route is being planned and there are two proposals, one an aerial route and the other an underground route.*

(a) Compare the advantages and disadvantages of EACH *type of route.*
(b) Using the information in the following table, determine which of the two proposals is the cheaper over a 20-year period.

Route	*Aerial*		*Underground*	
Equipment	*Poles*	*Cable*	*Ducts*	*Cable*
Capital Cost	*£2900*	*£2526*	*£4800*	*£2364*
Depreciation %	*2·76*	*3·32*	*0·42*	*2·69*
Maintenance %	*0·9*	*4·5*	*0·2*	*3*

Interest is at 10% per annum and the 20 year present value (PV) multiplier is 13·59

A2 (*a*) The advantages and disadvantages of an aerial route and an underground route are given in the following table:

Advantages	*Disadvantages*
AERIAL CABLE	
(*a*) Lower initial expenditure (*b*) Easier and quicker provision, particularly in rocky/difficult terrain.	(*a*) Higher maintenance due to exposure to the elements. (*b*) Shorter service life. (*c*) Route augmentation constrained by the carrying capacity of the poles and by the ground clearance of subsequent cables (particularly across roads, farm gates etc). (*d*) May be damaged by shotgun blasts in game areas. (*e*) Can be subject to objection on environmental grounds in areas of outstanding natural beauty.
UNDERGROUND CABLE	
(*a*) Lower maintenance costs. (*b*) Longer service life. (*c*) Greater capacity and easier cable augmentation. (*d*) More environmentally acceptable.	(*a*) Higher initial expenditure. (*b*) More difficult and time consuming to provide, particularly in rural situations where duct often has to be laid under carriageway.

(*b*) The total annual charges of either scheme

= annual charges for interest

+ annual charges for depreciation

+ annual charges for maintenance.

Aerial scheme

Annual charges for poles

$= (10 + 2{\cdot}76 + 0{\cdot}9)\%$ of £2900,

$= 13{\cdot}66\%$ of £2900,

= £396.

Annual charges for aerial cable

$= (10 + 3{\cdot}32 + 4{\cdot}5)\%$ of £2526,

$= 17{\cdot}82\%$ of £2526,

= £450.

Total annual charges

= £396 + £450,

= £846.

Present value of annual charges (PV of AC) over 20 years

= total annual charges × PV multiplier,

$= £846 \times 13{\cdot}59$,

= <u>£11 497</u>.

Underground scheme

Annual charges for duct

$= (10 + 0{\cdot}42 + 0{\cdot}2)\%$ of £4800,

$= 10{\cdot}62\%$ of £4800,

= £510.

Annual charges for cable

$= (10 + 2{\cdot}69 + 3)\%$ of £2364,

$= 15{\cdot}69\%$ of £2364,

= £371.

Total annual charges

= £510 + £371,

= £881.

The PV of AC over 20 years

$= £881 \times 13{\cdot}59$,

= <u>£11 973</u>.

For the aerial-route scheme, the PV of AC over 20 years

= <u>£11 497</u>.

For the underground-route scheme, the PV of AC over 20 years

= <u>£11 973</u>.

Therefore the aerial-route scheme is the cheaper over a 20 year period.

[*Tutorial Note:* As examinees were asked to use the information given in the question, calculations and conclusions would have been assessed on that basis. However, the capital costs and the depreciation and maintenance percentages given are not necessarily those found in practice. Also, the PV factor of 13·59 implies a test discount rate (TDR) of 4%, whereas, to be compatible with the interest rate of 10%, it should be at 10% TDR. In fact, as both schemes are assumed to be provided in year 1, the comparison can be made on the total annual charges alone.

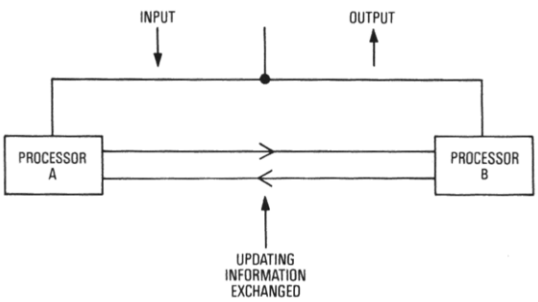
In practice, the ultimate capacity of each of the two proposed schemes should be borne in mind before the final decision is made. An aerial cable route can normally support, at the most, 200 pairs (2 × 100-pair cables) and more usually just 100 pairs (one cable). A single-bore duct route can cater for up to 800 pairs and possibly more, depending on bore size and the cables provided. Thus, if, for example, the route serves a remote community with its ultimate requirement, then aerial cable will be the obvious choice, but if the route is a through route where additional pairs will have to be provided, then the underground solution (on a cost-per-pair basis) is likely to be the most attractive.]

Q3 An exchange with stored-program control (SPC) may have its processors arranged using one of the following modes of working

(*i*) *synchronous-duplex (match-mode),*
(*ii*) *worker stand-by, and*
(*iii*) *load sharing.*

(*a*) *Explain the principle of* EACH *of these modes.*
(*b*) *Compare the advantages of the load-sharing mode with those of the other two modes.*

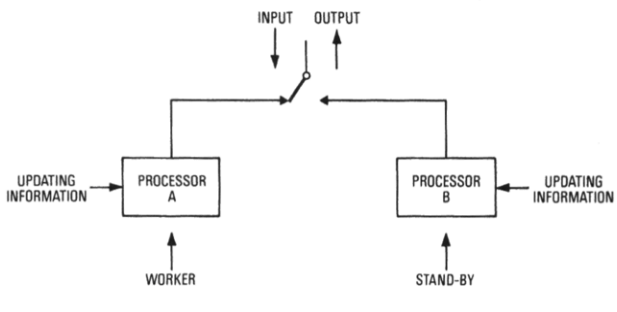
A3 (*a*) (*i*) The synchronous-duplex (match-mode) method of working processors is illustrated in sketch (*a*).



(*a*)

With this method of working, both processors work in unison, both performing exactly the same functions in response to individual input signals. In the event of the failure of one processor, the other processor can continue on. Any updating information is automatically copied between processors. It is, in effect, duplication of processors for security purposes. With some designs, the processor outputs are compared and, if found to be different, a self-checking algorithm is used on each processor separately to enable the faulty processor to be found.

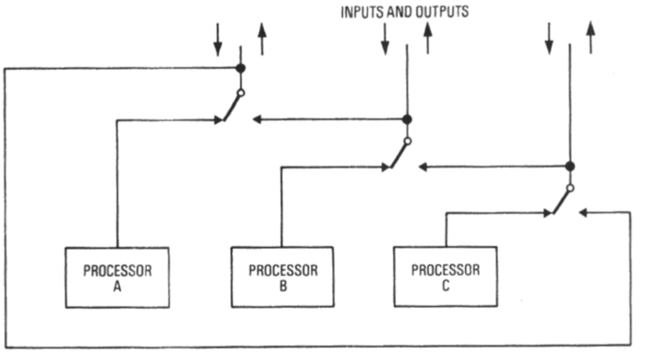
(*ii*) The worker stand-by method of working processors is illustrated in sketch (*b*).



(*b*)

With this method of working, only one processor is in operation at one time, that is the 'worker', while the other, that is the 'stand-by', is not in operation, but can be brought into service in the event of the 'worker' failing. This method allows for processors to be updated while in the stand-by mode. Some slight degradation of service is inevitable when switching from one processor to another.

(*iii*) The load sharing method of working processors is illustrated in sketch (*c*).



(*c*)

With this method of working, an exchange is divided into sections and one processor normally serves a particular section. In the event of a processor failure, the load is transferred to another processor. In the example given, if two processors failed the load would be placed on one processor.

(*b*) With the synchronous-duplex and worker stand-by modes of processor working, two processors have to be provided, but only one is in operation at one time; this is inefficient because the processor equipment is under utilised.

The load-sharing mode of working is more efficient because only sufficient processors are provided to meet the total load of the exchange. The design is such that, with the sectionalisation of the exchange, in the event of a processor failure, the load is transferred to another processor. Provided the degradation of service is not too drastic, this is acceptable in order to provide cost-reduced processor control.

Q4 *For a register-translator using stored-program control (SPC) explain, with the aid of block diagrams, how the following facilities are provided*

(*a*) *translator control,*
(*b*) *fault reporting and maintenance, and*
(*c*) *traffic metering.*

Q5 (*a*) *A controlling register-translator installation (group routing and charging equipment) serves a number of local exchanges, some of which may be charged at different rates for subscriber trunk dialled (STD) calls to the same destination.*

(*i*) *Explain with the aid of sketches, how this situation can arise.*
(*ii*) *State how the charging rate for the call is determined.*

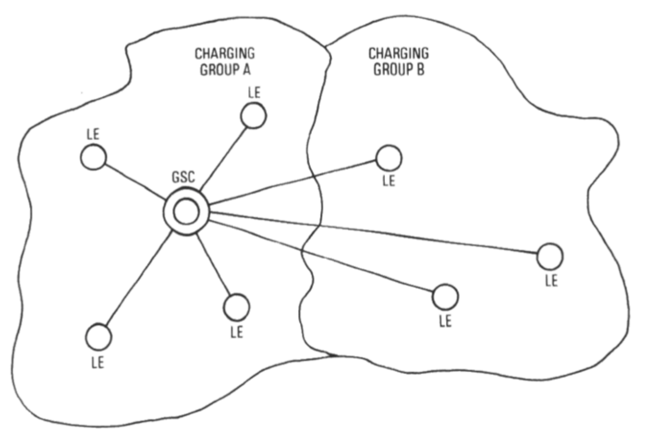
(*b*) *With the aid of sketches, describe the periodic metering method of charging for STD and local calls.*

A5 (*a*) (*i*) In many instances, a controlling register-translator (group routing and charging equipment) serves more than one charging group. Sketch (*a*) shows such a situation with charging group A containing the group switching centre (GSC) and various local exchanges (LEs), this being known as the *home charging group*; and LEs in an adjacent charging group, charging group B, relying on the GSC in charging group A for incoming and outgoing subscriber trunk dialling (STD) calls, this being known as a *dependent charging group*.

As the charging rate for STD calls is dependent on the distance between the calling and called charging groups, then, for STD calls, the distance between charging group A and the called charging group, and charging group B and the called charging group could be different. Any difference in distance means that different charge rates must be applied to particular calls, depending on whether they originate from LEs in charging group A, or LEs in charging group B. Hence the register-translator installation at the GSC may need to apply different charge rates to calls which originate in charging group B from those charge rates applied to calls which originate in charging group A, even though the calls may be to the same destination.

(*ii*) The charging rate for the call depends on the distance and on the tariff period (the time of day).

When an STD call originates in the home charging group, for a specific destination, the register receives the digits identifying the called



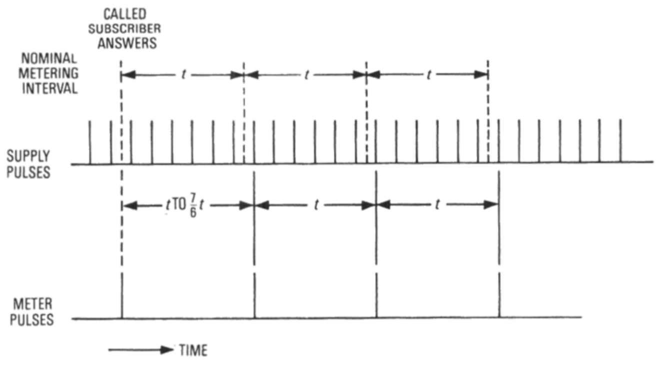
GSC: Group switching centre
LE: Local exchange

(*a*)

number. Usually the first three digits of the national number identify the national numbering group code, but there may be up to five digits. The register applies to the translator, which determines the fee digit to be applied. This fee digit is returned to the register for subsequent sending to the register-access relay-set.

STD calls originating in the dependent charging group would use a different group of register-access relay-sets from those used for home-charging-group calls. In this case, it is arranged that the register-access relay-set passes a discrimination signal to the register, which further extends it to the translator. This allows a different fee digit to be returned to the register and ultimately to the register-access relay-set.

(*b*) For STD calls, the register-access relay-set controls the application of meter pulses. The fee digit is used to select one of a number of pulse supplies in preparation for metering. The metering rate is a function of the distance between callers and the time the call originates. On receipt of the *answer* signal from the called customer, the register-access relay-set sends one meter pulse which directly or indirectly operates the calling customer's meter and, in effect, charges for the initial interval irrespective of the periodic metering rate applicable. At the same same time, the preselected pulse supply is connected to a counter within the relay-set. The supply pulses are run at six times the frequency of the corresponding meter rate, while the counter is so designed that it causes the relay-set to deliver one meter pulse when the seventh supply pulse is received, and, thereafter, one meter pulse for every six supply pulses received. By means of this device, the second and subsequent metering intervals are precisely timed, but the first interval is, in general, greater than the nominal value. The effect is illustrated in sketch (*b*) from which it can be seen that any departures from the nominal metering interval operates in the customer's favour.

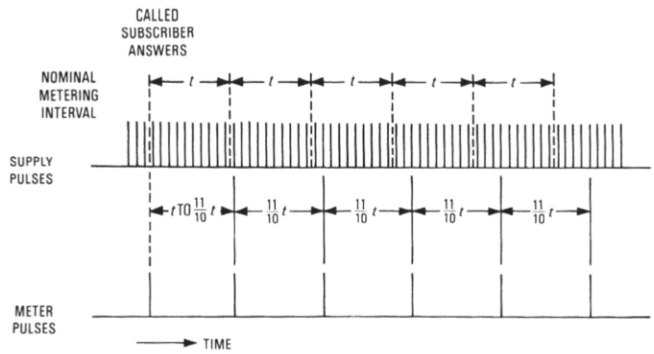


(*b*)

For local calls, the method of charging follows the same general pattern as trunk-call charging and the register-access relay-sets make provision for metering any local calls which are set up by means of the register-translators. The great majority of local calls are not routed in this way, however, and periodic metering is provided at local exchanges using local-call timers.

The principle on which local-call timers operate is different from trunk-call metering. When a local call is answered, an initial meter pulse is registered, normally by an *answer* signal sent back to the calling customer's exchange, to charge for the first time interval. The meter pulse is also detected in the local call timer, where it is used as a signal to

connect a pulse supply running at 10 times the local metering rate. The supply pulses are counted in the local-call timer and a meter pulse is delivered for every 11 supply pulses received. The use of this technique safeguards the calling customer against loss of paid time during the first interval (sketch (*c*)). It does, however, permit the equipment to be cheaper than it would be if each subsequent interval were of a nominal duration.



(*c*)

[*Tutorial Note:* Although the Strowger system has been described, the principle of periodic metering is similar for crossbar trunk and local exchanges and electronic local exchanges.]

Q6 For a national telephone network:

(*a*) *state the purpose of a national numbering scheme;*

(*b*) *sketch and describe* THREE *ways in which subscriber trunk dialling (STD) traffic may be routed between two group switching centres (GSCs);*

(*c*) *state* FIVE *factors which determine the choice of routing; and*

(*d*) *explain why there is a limit to the number of 2-wire switching centres through which a call may be routed.*

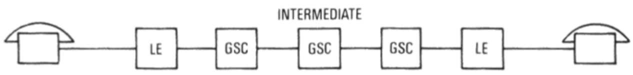
A6 (*a*) The purpose of a national numbering scheme is to provide each telephone customer within a country with a unique telephone number, so that any customer can gain access to any other customer within the national numbering scheme by dialling just the wanted-customer's national number, without having to refer to local dialling-code instructions.

(*b*) Sketch (*a*) shows a call routed between two GSCs over a direct single-link trunk or junction circuit. Such circuits are provided where the level of traffic is sufficient to justify a direct GSC-to-GSC route.

LE: Local exchange

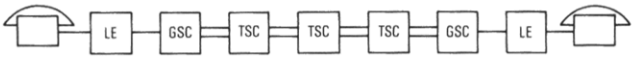
(*a*)

Sketch (*b*) shows a call routed between two GSCs via an intermediate GSC. This type of routing occurs where the level of traffic is insufficient to justify a direct route, but is sufficient to justify a tandem routing via an intermediate GSC, provided there is sufficient switching capacity at the intermediate GSC.



(*b*)

Sketch (*c*) shows a call routed between two GSCs via three transit switching centres (TSCs) and the transit network. This type of routing in provided where the level of traffic is insufficient to justify even a tandem routing, as in sketch (*b*).



(*c*)

(*c*) The factors determining the choice of routing are:

(*i*) whether the level of traffic justifies the provision of a direct GSC-to-GSC route;

(*ii*) for lower levels of traffic, whether a tandem routing via an intermediate GSC is available;

(*iii*) if such a tandem routing is available, whether there is sufficient equipment capacity at the intermediate GSC to cope with the expected level of tandem traffic;

(*iv*) whether there would be excessive post-dialling delays on a tandem routing; and

(*v*) whether the transmission quality would be acceptable on a tandem routing.

(*d*) The number of 2-wire group switching centres through which a call can be routed is limited to three for the following reasons:

(*i*) The controlling register-translator equipment may not be capable of sending sufficient routing digits to route the call over more than two links.

(*ii*) Three or more links in tandem can unacceptably reduce the level of transmission.

(*iii*) An unacceptable post-dialling delay (the delay between the end of dialling and the reception of the supervisory tone) could be introduced, particularly on long routings.

Q7 (*a*) *For a common control transit switching centre (TSC), describe* THREE *of the essential features required for routing, switching and signalling in the exchange.*

(*b*) *With the aid of a trunking diagram, describe briefly how a call is routed through a crossbar-type transit exchange.*

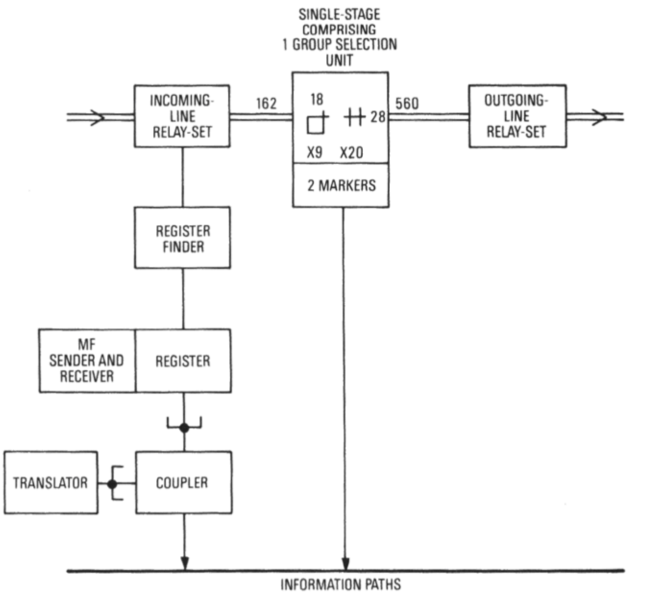
A7 (*a*) For a common-control transit switching centre, the three essential features required for routing, switching and signalling in the exchange are as follows:

(*i*) All routes in the transit network are 4-wire terminated at the transit switching centres (TSCs) and it is a prime function of the TSC to connect incoming circuits to outgoing circuits, as required, via 4-wire switching equipment.

(*ii*) In order to avoid the risk of interference between speech and signalling, the signalling path between the incoming-line and outgoing-line terminations are repeated through the switching in a DC form, separate from the speech paths.

(*iii*) It is fundamental to the trunk transit-switching plan that the switching equipment at TSCs is register controlled. All TSCs are alike in principle and perform their switching function on receipt of a three-digit code. This code is sufficient to identify the terminal centre to which the call is to be routed via the transit network, and it is used at each TSC in the connection to select the appropriate outgoing route. Operation on the basis of a short code of uniform length, with registers at TSCs controlling only their own switching equipment, simplifies design and leads to economy in the provision of common equipment.

(*b*) A simplified trunking diagram of a TSC using crossbar switches is given in the sketch. The trunking shown is suitable for small centres having less than 162 lines.



The seizure of an incoming-line relay-set causes a register to be associated via the register-finder crossbar switches. When connected, this register and its multifrequency (MF) sender and receiver return an MF *transit-proceed-to-send* signal; in response to this signal, the controlling register at the originating centre sends the first three stored digits. The digits are received, stored and checked in the TSC register. Meanwhile, this register has seized a coupler, which, in turn, seizes a translator to which the three code digits are passed. At the same time, the coupler signals the primary section connected to the incoming-line relay-set to seize one of the two markers in that group selection unit, which then selects and seizes a free information path. The identity of this path is returned to the coupler via the primary section, incoming-line relay-set and register. The translator passes the translation to the coupler and is then released; the coupler connects itself to the information path concerned, which is used for passing the translation from the coupler to the marker. The information path is released as soon as the translation has been given to the marker, the marker proceeding to effect a connection between the incoming circuit and free circuit in the required route. This is achieved by selecting a secondary section having a free circuit in the outgoing route and to which there is a free link from the calling primary section.

The free circuit and the free link are selected at this stage by the operation of the magnets of the select bars in both secondary and primary sections. The marker again chooses and seizes an information path, indicates the path to the coupler, and the coupler connects itself to it. A signal from the marker to the register, via the coupler, indicates that it is ready for completion of the connection; the register does this by operating the primary-section and secondary-section selector magnets in turn. The information path, coupler and marker are released, and the register makes a DC continuity check over each wire switched at the crosspoint before initiating its own release, thereby releasing the register finder and allowing the incoming-line relay-set to connect line to line.

The routes from a TSC can be made up of wholly undirectional circuits, wholly bothway circuits or a mixture. Information indicating the state of a whole route is fed to the translator, and, when a translation is given, it is left to the marker to select an available free circuit in a route. For mixed routes, outgoing circuits are tested by the marker before bothway circuits.

Q8 *(a) An international direct dialled (IDD) call is made from a local telephone exchange in the UK to a subscriber in Sydney, Australia. The world numbering code for Sydney is 612 and the required number on the local exchange in Sydney is 2076. A direct route is not available but one exists via an intermediate international transit exchange. Write down and explain the digits which are*

(i) dialled by the calling subscriber,
(ii) received by the outgoing international gateway exchange,
(iii) received by the intermediate international transit exchange, and
(iv) transmitted by the intermediate transit exchange.

(b) Describe the North American zone integrated number plan. Briefly explain how codes are allocated.

Q9 *With reference to a call connected via the international network:*

(a) draw a block diagram showing the most adverse route that the call may take and allocate transmission losses to each part;

(b) explain the term 'virtual switching points' and state how they are related to the nominal loss on an international link; and

(c) state the CCITT recommendations on stability for the national part of the network and describe TWO arrangements that would satisfy these recommendations.

A9 (*a*) A block diagram of a call connected via the international network with the most adverse routing is given in sketch (*a*).

The transmission losses for the most adverse routing are made up as follows:

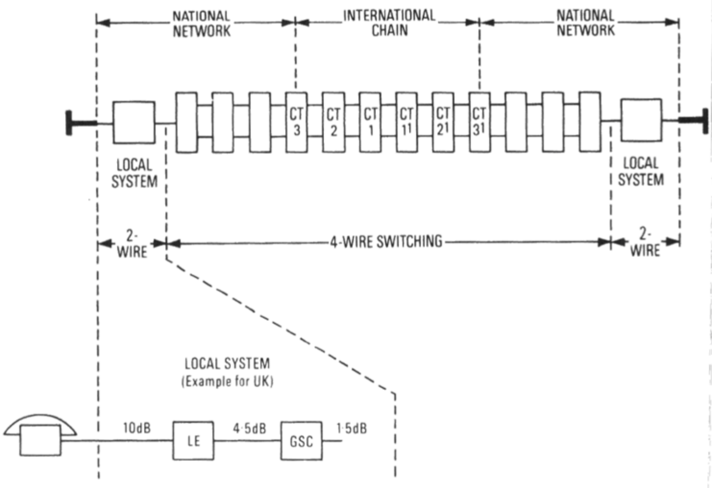
Customer to exchange 2-wire connection = maximum of 10 dB (for each end)

Local system (2-wire switched connection) = 4·5 dB + 1·5 dB switching losses (for each end)

National network (4-wire switched connection) = 0·5 dB per link

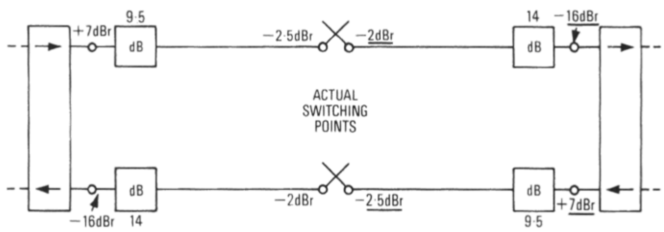
(*b*) Virtual switching points are points existing for the purpose of definition for the CCITT recommendations. The CCITT recommendations are defined in terms of a switching level of −3·5 dBr, but, in recognition of the fact that any level can be chosen, −3·5 dBr is taken to be the send level at what are termed *virtual switching points.*

Sketch (*b*) shows the actual arrangement in an international switching centre with a send level of −2 dBr. The send level of −16 dBr and the receive level of +7 dBr are examples only; any suitable levels could apply. Sketch (*c*) illustrates how the −3·5 dBr virtual switching points can be identified in such a switching centre.

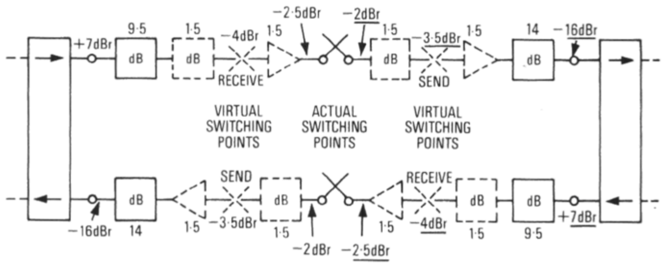


CT: *Centre du transit*

(*a*)



(*b*)



(*c*)

The relative power (dBr) is the power at one point in a circuit referred to a specific reference point at some other point. In sketches (*b*) and (*c*) the underlined values of relative level at any point refer to the circuit to the right of that point; those not underlined refer to the circuit to the left. The zero relative-level points for each circuit are independent, and a suitable connection has no defined point of zero relative level.

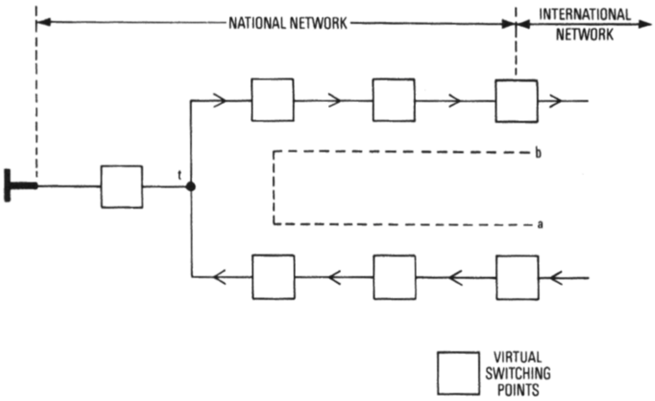
For a real switching centre, virtual switching points need not exist, but, by introducing suitably-valued hypothetical pads and amplifiers (shown dotted in sketch (*c*)), the location of the virtual switching points can be found. They are connected together without the interposition of any additional net gain or loss; that is, the 1·5 dB pad cancels out the 1·5 dB amplifier, with the actual switching points being assumed to introduce negligible loss.

The nominal transmission loss, at the reference frequency (800 Hz), assigned to an international circuit for stability reasons, is normally 0·5 dB, so that the relative receive level at the actual switching points in the example shown in the sketches is −2·5 dBr.

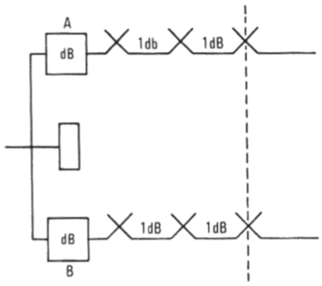
(*c*) The CCITT recommendations concerning stability (G122) state that the attenuation of the path a-t-b (sketch (*d*)) should not be less than 6 + *n* decibels, where *n* is the number of 4-wire circuits in the national chain.

Administrations are also recommended to aim for a mean value for the attenuation of the path a-t-b of at least 10 + *n* decibels, with account being taken of the actual distribution of calls.

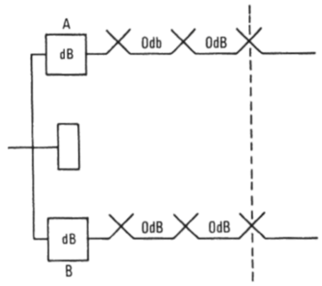
Two arrangements that would satisfy the recommendations are given in sketches (*e*) and (*f*).



(*d*)



(*e*)



(*f*)

In sketch (*e*),

$$\text{required a-t-b attenuation} = 6 + n\,,$$
$$= 8\,\text{dB} \quad (\text{if } n = 2),$$

Hence, $A + B \geqslant 4\,,$

assuming 0 dB minimum balance return loss.

In sketch (*f*),

$$\text{a-t-b attenuation} = 6 + n\,,$$
$$= 8\,\text{dB} \quad (\text{if } n = 2).$$

If minimum balance return loss is 2 dB,

$$A + B \geqslant 6\,.$$

Q10 *For a space-division international switching centre (ISC) using common control:*

(*a*) *sketch and describe an automatic accounting system employing computers (processors); and*

(*b*) *explain how the following information can be obtained from the system*

(*i*) *traffic statistics, and*

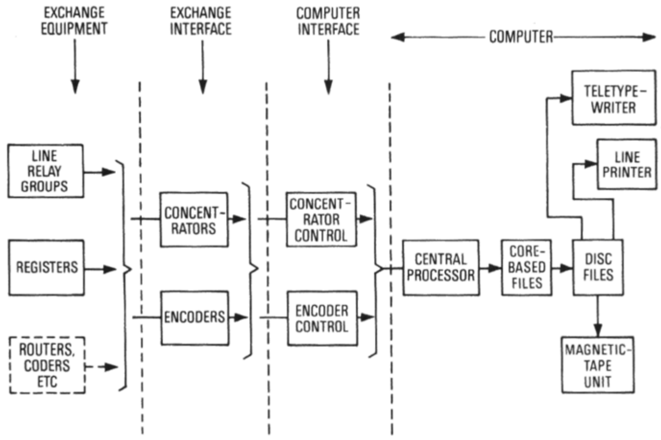
(*ii*) *engineering performance statistics.*

A10 (*a*) A block schematic diagram of the essential features of the international accounting and traffic analysis equipment (IATAE), used with a large space-division common-control international switching centre (ISC), is given in the sketch.

The IATAE is based on a commercially available computer with specially designed interfaces to connect the computer to the ISC. A 2-stage interface is used to connect from high-level (50 V) slow-speed signals from the ISC to low-level (5 V) high-speed signals suitable for input to the computer. The first stage (exchange interface), in the ISC close to the trunk circuits, concentrates signals from 1000 circuits into a 10-wire highway to the second stage of the interface; similarly, the routing information is assembled by encoders ready for the computer to read. The second stage (computer interface) takes the 5 V outputs of the first stage and further concentrates a number of these 10-wire highways into the input-output highway of the computer.

The control computer configuration consists of an on-line and off-line system. The on-line system performs most of the necessary tasks and consists of one central processing unit, a core store, four disc storage systems, a line printer, teletypewriter and other slow-speed peripheral devices. The off-line system consists of one central processing unit, a core store, magnetic tape units, a line printer and a teletypewriter. Its major function is to act as stand-by to the on-line system and to process magnetic tapes from the accounting program.

The IATAE takes information from the ISC through a number of paths. Each incoming and outgoing circuit, and each item of common equipment, is connected via concentrators and scanned by the computer



at various rates. Information gathered from the trunk circuits is SEIZURE, CLEAR, ANSWER, and BUSY FOR MAINTENANCE, and from the common equipment SEIZURE and CLEAR. Further information is collected from incoming decoders to determine the destination and outgoing route of the call.

The software is composed of supervisor and application programs. The supervisor is the software that schedules running of the application programs, together with optimising the use of the system hardware to maximise system throughput.

The application programs are those that fulfill the particular IATAE functions. A predefined sequence of events takes place every half hour, as defined by a timing program in the supervisor. A suite of programs is activated, which takes the basic data collected from the ISC, performs validation and confidence checks and further processes them, in response to requests for output at the required locations. A comprehensive operator communication language enables users to give instructions to the IATAE.

(*b*) (*i*) Traffic statistics are gathered from each circuit and each item of common equipment for use by exchange planners. The information relates to the traffic levels experienced by the exchange normally during the busiest hour of the day. All the information normally collected can be used; that is, SEIZURE, CLEAR, ANSWER and BUSY FOR MAINTENANCE for trunk circuits; SEIZURE and CLEAR for common equipment (registers, router controls etc); and destination and outgoing route of calls, from incoming coders. The information is recorded on an hourly basis and is available only if requested by a user, and is output on the line printer.

(*ii*) Engineering performance statistics can be collected by the IATAE to enable faults to be located quickly in the exchange (mainly the common equipment) and on the circuits. The information is identical to that normally gathered for accounting and traffic statistics. The information is normally stored on a magnetic disc, which is overwritten every half hour, and it is output only if it has been specificaly requested (unlike accounting data, which is accumulated over a one-month period). A user accesses the system by inputting requests at a teletypewriter. The teletypewriter can receive only small amounts of data; therefore the data is checked and the user can request it to be output on a line printer.

Answers contributed by J. R. Bush

BACK NUMBERS

The price of back numbers of the *Journal* is £1.75 each (75p to staff of British Telecom and the British Post Office), including the Supplement and postage and packaging. (The *Supplement* is not sold separately.) Back issues can be ordered by using the form printed below.

BTEC AND SCOTEC: GUIDANCE FOR STUDENTS

Details of back issues of the *Journal* with *Supplements* containing question/answer material for students following the syllabi of the Business and Technician Education Council and the Scottish Technical Education Council courses for telecommunications technicians are given below.

BTEC Units

Digital Techniques II	Apr. 1983, Apr. 1984, Apr. 1985
Digital Techniques A III	Oct. 1983, July 1984, Oct. 1985
Electrical and Electronic Principles II	July 1983, Apr. 1984, Oct. 1985
Electrical and Electronic Principles III	Oct. 1983, Oct. 1984, Jan. 1986
Electrical Principles II	Jan. 1980, Jan. 1981, July 1982
Electronics II	Oct. 1980
Electronics III	July 1983, Apr. 1984, July 1985
Line and Customer Apparatus I	Jan. 1979, July 1981, Apr. 1982, Apr. 1983, Apr. 1984
Lines II	Apr. 1981, Oct. 1982, Apr. 1984, Apr. 1985, Apr. 1986
Lines III	July 1983, Apri. 1986
Mathematics I	Jan. 1979, Apr. 1980
Mathematics II	Apr. 1980, Apr. 1982, July 1983, Apr. 1984, July 1985, Apr. 1986
Micro-Electronic Systems I	July 1983, Apr. 1984, Apr. 1985
Micro-Electronic Systems II	Oct. 1983, July 1984, July 1985
Physical Science I	Jan. 1979, Jan. 1980, July 1981
Radio II	Jan. 1983, Jan. 1984, Apr. 1985
Telecommunication Systems I	Jan. 1980, July 1981, July 1982, July 1983, Jan. 1984, Jan. 1985
Telephone Switching Systems II	Jan. 1980, Oct. 1982, Oct. 1983, July 1984, Oct. 1985
Telephone Switching Systems III	Jan. 1983, Oct. 1984, Apr. 1986
Transmission Systems II	July 1980, Jan. 1982, Jan. 1983, Jan. 1984, Jan. 1985, Jan. 1986
Transmission Systems III	Apr. 1983, Oct. 1985

SCOTEC Subjects

Introduction to Telecommunications Systems	Jan. 1979, Apr. 1982*
Digital Techniques and Transmission	July 1982*, Jan. 1984*
Electrical and Engineering Principles	Jan. 1979
Electrical Principles II	Jan. 1983
Electrical Principles III	July 1982*, July 1983*, July 1984*
Electronics III	Oct. 1982*
Mathematics I/II	Jan. 1979
Mathematics III	July 1982*, Apr. 1983*
Mathematics IV	Oct. 1984*
Radio III	Oct. 1982*, Jan. 1984*
Switching Systems III	Apr. 1982*, July 1983*
Telecommuncation Transmission Systems V	Oct. 1984*
Transmission Systems III	Oct. 1984*

CITY AND GUILDS OF LONDON INSTITUTE

(Answers to examination papers set by CGLI. Year of paper shown in brackets)

Circuit Theory T4	Apr. 1986 (1985)
Switching T4 Option	Jan. 1986 (1985)
Switching T5 Option	Apr. 1986 (1985)

EDUCATIONAL PAPERS PUBLISHED IN THE SUPPLEMENT

Field-Effect Transistors	Oct. 1982
Microcomputer Systems (Part 1)	Oct. 1984
Microcomputer Systems (Part 2)	Jan. 1985
Digital Multiplexing	Apr. 1986

The January and April 1982, and the January 1985 back issues are no longer available.

To: British Telecommunications Engineering (Sales),
Post Room, 2–12 Gresham St.
London EC2V 7AG.

Please send the following back issues of *British Telecommunications Engineering* ....

....

....

Name .... Address ....

I enclose a cheque/postal order* for £ ....

....

*Cheques and post orders, payable to **'BTE Journal'**, should be crossed '& Co.'. Cash should not be sent through the post.
Please state clearly if you are ordering more than one copy of each issue.
Orders should be addressed to *British Telecommunications Engineering Journal* (Sales), Post Room, 2–12 Gresham Street, London EC2V 7AG.

Published by *British Telecommunications Engineering Journal*, 2–12 Gresham Street, London EC2V 7AG
and printed in Great Britain by Unwin Brothers Limited, Old Woking, Surrey